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THE JUNE SCIENTIFIC MONTHLY

EDITED BY J. McKEEN CATTELL

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The preliminary report of the second season of exploration of the ruins in northern Syria. They are being conducted by Yale University and the French Academy of Inscriptions and Letters.

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Brain and Personality. Paul Schilder. v + 136 pp. $3.00. Nervous and Mental Disease Publishing Company.

This monograph consists of two series of lectures, the first on studies in the psychological aspects of cerebral neuropathology, the second on the relation between the personality and motility of schizophrenics.

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The authors endeavor to describe how the mind works, thus helping the reader to a better understanding of himself. The book is divided into the two parts: the conceptions of modern psychology and the psychology of everyday life.

THE SCIENTIFIC MONTHLY

JUNE, 1931

THE NEW BERMUDA BIOLOGICAL STATION FOR RESEARCH

(INCORPORATED 1926)

By Professor EDWIN G. CONKLIN

PRESIDENT OF THE BOARD OF TRUSTEES OF THE STATION
DEPARTMENT OF ZOOLOGY, PRINCETON UNIVERSITY

THE peculiar advantages of Bermuda for biological and oceanographic studies have been made known by numerous investigators and by several scientific expeditions. In 1859 J. Matthew Jones, Esq., F.L.S., barrister of the Middle Temple, published a book of 200 pages entitled "The Naturalist in Bermuda," which Charles Darwin in his "Origin of Species" called an "admirable account." In 1876 Mr. Jones published a "Visitor's Guide to Bermuda," containing a list of the more common plants and animals, and in 1884 he and G. Brown Goode, with the collaboration of five other specialists, published in the Bulletin of the U. S. National Museum an extensive work on "The Natural History of the Bermudas"—their geology, physiography, botany and zoology. The famous *Challenger* Expedition visited Bermuda in 1873 and made a special study of the ocean depths surrounding the islands; various volumes of the reports of that expedition contain matter relative to the geology, meteorology, botany and marine zoology of Bermuda. Angelo Heilprin in 1889 published a valuable volume on the natural history of "The Bermuda Islands." Alexander Agassiz visited Bermuda in 1894 and studied particularly the ocean depths and slopes around the islands, the sounds, lagoons and coral reefs with especial reference to the method of formation of coral islands. In 1902 and 1907 Addison E. Verrill published in the Transactions of the Connecticut Academy of Arts and Sciences two volumes on "The Bermuda Islands; Their Scenery, Climate, Physiography, Natural History, Paleontology and Coral Reefs, with Sketches of Their Early History and the Changes Due to Man." Most recent of all, and in some respects most distinctive, are the expeditions of the New York Zoological Society under the directorship of William Beebe during the years 1929 to 1931; this expedition is devoting particular attention to the deep sea fauna, and actual descents have been made to depths far greater than have ever before been reached by man.

These are but a few of the many scientific studies relating to Bermuda, all of which indicate the wealth of opportunity which these islands afford for research work in the natural sciences.

(1) THE ORIGINAL BERMUDA BIOLOGICAL STATION FOR RESEARCH

The idea of creating in Bermuda a laboratory for biological studies in con-

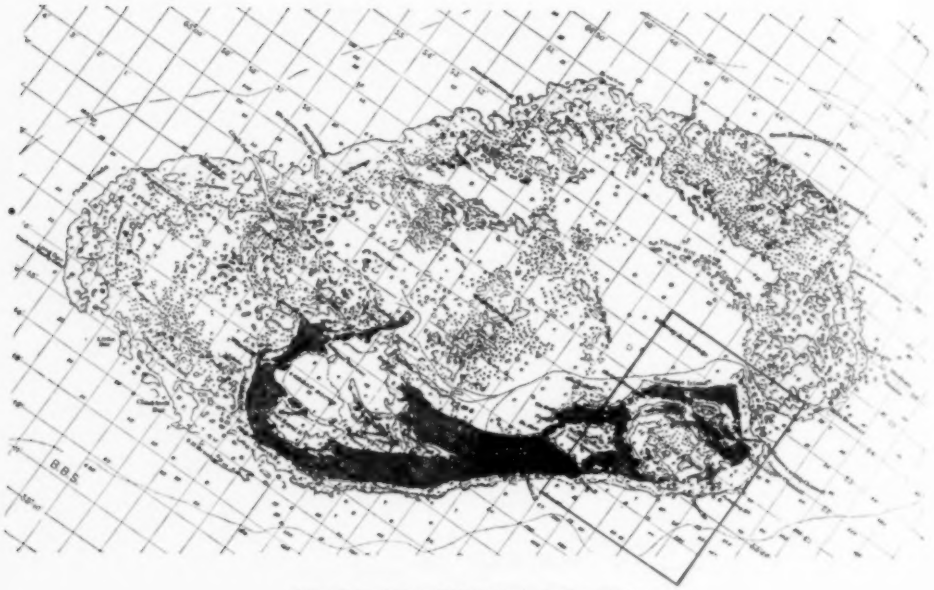


CHART OF BERMUDA ISLANDS

nection with a public aquarium was suggested as early as 1896, and later the Bermuda Natural History Society was organized with the purpose of furthering such an undertaking. Half a dozen years, however, elapsed before definite results were attained. In 1903 Harvard University and New York University entered into an agreement for the establishment and joint support of the Bermuda Biological Station for Research, with Professor Edward L. Mark as director and Professor Charles L. Bristol as associate director, it being understood that the station was ultimately to be associated with the public aquarium which the colony contemplated establishing. After a careful study of the needs of the aquarium as well as the opportunities for carrying on scientific investigations, the Flatts at the Inlet to Harrington Sound was selected as the location of the station. Provision was made for laboratory facilities as well as for the board and lodging of investigators at the Hotel Frascati, and a printed circular was issued inviting zoologists and botanists

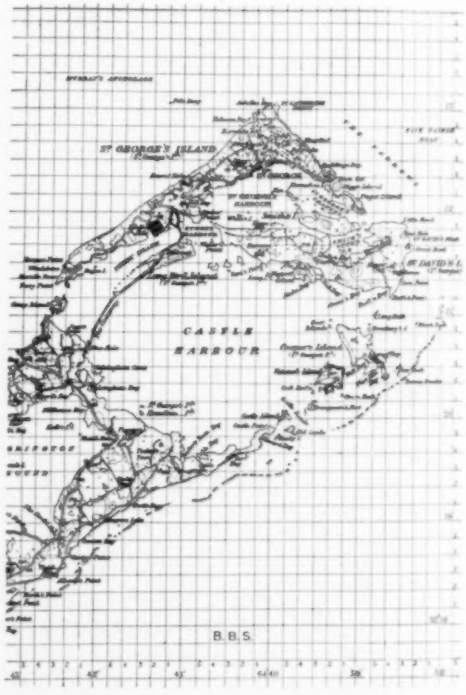


CHART OF N. E. RECTANGLE
SHOWN IN HEAVY OUTLINES IN CHART OF BERMUDA ISLANDS, SHORE HILLS AREA, CROSS-HATCHED.

to share in the opportunities of the station without the payment of any laboratory fees. There were in attendance at this first session of the station—June 22 to August 22, 1903—between thirty and forty workers. The summer session was repeated under the same conditions in 1904 and 1905. In 1906 the colony purchased at the Flatts a plot of land for the erection of the aquarium and station, but owing to straitened circumstances was unable to carry out the rest of the plan. Within a year, however, the Natural History Society leased from the War Department Agar's Island and converted its "magazine" into a public aquarium. Meanwhile the agreement between New York and Harvard Universities had been abrogated, and the society invited Professor Mark, as the representative of Harvard University, to take over the management of the station at Agar's Island. The station has been in continuous existence there since 1907, the opportunity for work at other times than the regular summer sessions having been provided for as occasion arose. For nearly three years (1915–1918) Dr. William J. Crozier was resident naturalist at the station, and Mrs. Crozier was librarian and recorder. About 280 scientists have carried on studies at the station, and the printed publications of their researches now amount to upwards of 160 papers arranged in seven volumes.

From the spring of 1917 to 1919 Agar's Island was requisitioned for military purposes, and the whole equipment of the station was transferred for that period to Dyer's Island, a short distance away. After the World War the aquarium at Agar's Island was discontinued, and the island was leased from the War Department by Harvard University for the exclusive use of the station, which was continued there until the opening of the reorganized station at Shore Hills. In the meantime a splendid public aquarium was established on the site originally selected at the Flatts, but leaving no suitable space for an enlarged biological and oceanographic station, such as was contemplated in the plan of reorganization.

(2) The Reorganized Bermuda Biological Station for Research, Inc.

In August, 1925, twelve persons who had worked at the Bermuda Station, including Dr. E. L. Mark, its director, met in Woods Hole, Massachusetts, and formulated a letter which was sent to many biologists in Great Britain, Canada and the United States asking for their cooperation in forming a corporation to make the station more widely useful as an international laboratory, and requesting the nomination of five persons to serve as a committee on reorganization. Letters of cordial endorsement of the project were received from the Royal Society of London, the Royal Society of Edinburgh, the Royal Society of Canada, the Biological Board of Canada, the Honorary Advisory Council for Research (Canada), the National Research Council, of the United States, and from many other scientific institutions and persons. One hundred and thirty-four persons (later increased to 180) joined the corporation and the following committee on reorganization was elected: C. L. Bristol, E. G. Conklin (chairman), E. V. Cowdry (secretary), E. L. Mark and H. W. Rand. The committee drew up articles of incorporation and by-laws and nominated sixteen members of the corporation to be trustees, the twelve receiving the highest number of votes to be declared elected. By the votes of more than 150 members of the corporation twelve trustees were elected, eight of them residents of the United States, two of Great Britain, and one each of Bermuda and Canada. On June 28, 1926, the Bermuda Bio-

SHORE HILLS SEEN FROM SOUTH ACROSS FERRY BEACH
ESSEX HOUSE ON RIGHT; COTTAGES AND BATHING PAVILIONS ON LEFT.

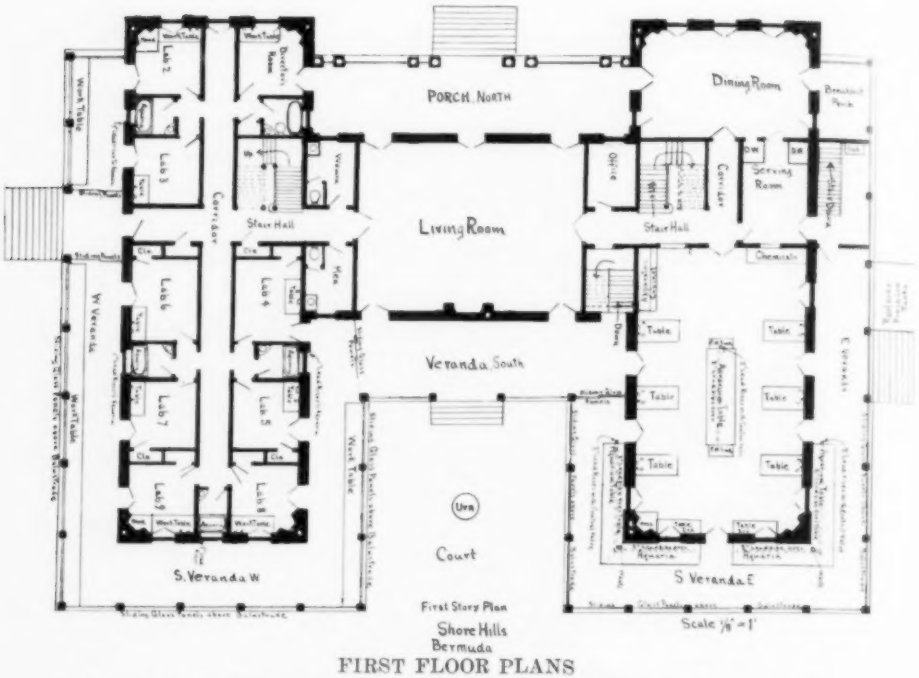
SHORE HILLS FROM SOUTHEAST

SHOWING VERANDAS AND SLEEPING PORCHES.

logical Station for Research was incorporated under the laws of the State of New York.

On April 23, 1930, a special meeting of the corporation and trustees was held in New York for the purpose of amending the articles of incorporation so as to permit the enlargement of the board of trustees to twenty-four persons, and on April 26 the amended charter was approved by the proper authorities of the State of New York. At the annual meeting, January 3, 1931, eight additional members were elected to the board of trustees, which now consists of twenty persons, thirteen from the United States, three from Bermuda, and two each from Great Britain and Canada.

Special meetings of the trustees were held in August and October, 1926, and the first annual meeting of the corporation and trustees was held in New York on December 27, 1926. At that meeting officers were elected, an executive committee appointed, and a report received from a committee of four trustees that had visited Bermuda to select a site for a permanent station. After this committee had inspected more than twenty proposed sites they reported in favor of a tract of 12 acres in St. George's Parish, fronting on Ferry Reach and Mullet Bay, and known as "The Hunter Tract," which could be purchased for £5,500. This site was approved by the trustees and corporation, and later a petition was addressed to the governor and legislature of Bermuda asking (1) that the Bermuda Biological Station for Research, Inc., be granted the privilege of holding real estate in the Islands of Bermuda; (2) that when the trustees should satisfy the governor-in-council

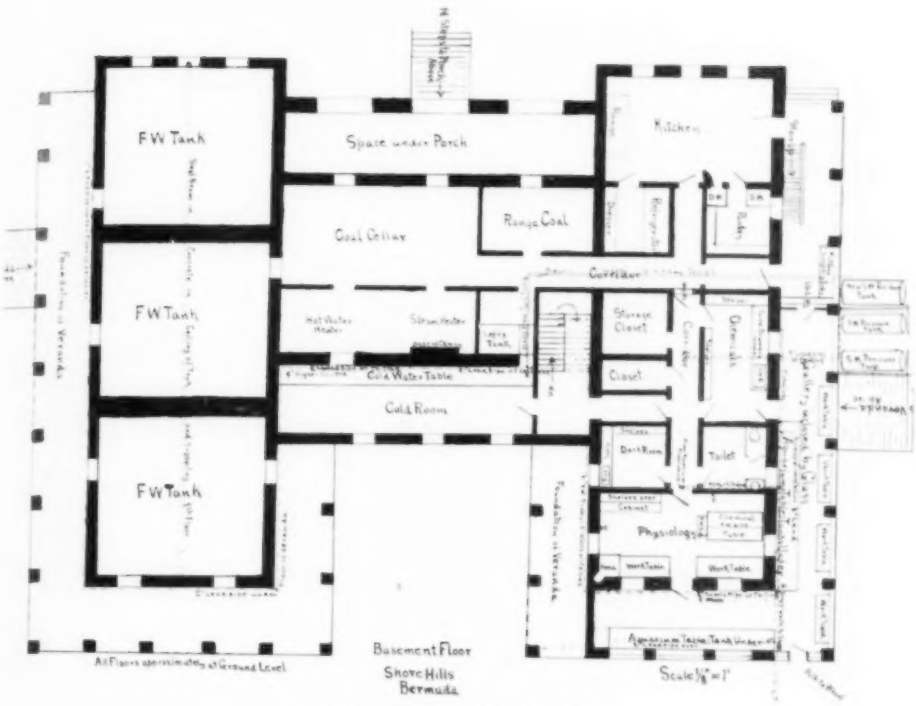


FIRST FLOOR PLANS

SHOWING ARRANGEMENT OF LABORATORY ROOMS, AQUARIA, LIVING ROOMS, ETC.

that not less than £50,000 endowment had been raised, the Colonial Government should purchase and transfer to the trustees the Hunter property; (3) that all supplies and equipment imported for the purposes of the station be exempted from customs duties; (4) that an annual grant of £200 a year for a period of ten years be made by the Bermuda Government for the support of the station. On June 24, 1927, the legislature of Bermuda passed the "Biological Station Act of 1927," enacting each and all of these articles.

With this friendly and generous action on the part of the Government of Bermuda, the trustees applied to the General Education Board of the Rockefeller Foundation for a grant to meet the conditional gift by the Government of Bermuda and to provide for the development and maintenance of the station. In the meantime the National Academy of Sciences of the United States had appointed a committee on oceanography which, with the aid of a grant from the Rockefeller Foundation, undertook the preparation of an extensive report on the needs and opportunities of this branch of science; the Foundation therefore postponed action on the application of the Bermuda trustees until this could be considered in connection with the report of the committee on oceanography. This report of 165 typewritten pages recommended that an oceanographic institution be established in a central location on the Atlantic Coast and that this "be supplemented by two branch stations, one sub-arctic and the other truly oceanic in location. The latter location would be served admirably by the Bermuda Biological Station for Research, Inc., which has the support of the committee in its efforts to complete its organization." This report was approved by the National Academy of Sciences in



BASEMENT FLOOR PLAN

SHOWING ARRANGEMENT OF LABORATORY ROOMS, AQUARIA, ETC.

November, 1929, and on November 13 of that year the Rockefeller Foundation appropriated £50,000 to meet the condition imposed by the Bermuda Legislature; on March 29, 1930, the Hunter Tract was purchased by the Government of Bermuda and conveyed to the trustees, and on April 4, 1930, the Rockefeller Foundation paid to the Bermuda Biological Station for Research, Inc., £50,000.

A committee of the trustees visited Bermuda in February, 1930, employed a local architect and began preparation of plans for a new laboratory, boathouse, wharves, and the remodeling of the old residence on the Hunter Tract. In July and August, 1930, the president and treasurer were in Bermuda with the intention of letting contracts for the buildings, but the plans were not in final form and little progress was made.

(3) The New Station at "Shore Hills," St. George's, Bermuda

At that time a large sanitarium-hotel property known as "Shore Hills," almost adjoining the Hunter Tract, was offered for sale at a very low price and some of the leading citizens of Bermuda suggested that the trustees reconvey to the government the Hunter Tract on condition that the government appropriate £5,500 toward the purchase of "Shore Hills." This proposal was approved by the trustees, the Rockefeller Foundation, and finally by the Government of Bermuda, and on March 26, 1931, the trustees took possession of "Shore Hills," one of the finest properties in St. George's Parish, consisting of more than 14 acres of land fronting on Ferry Reach, with a main building of stone and concrete, which will be used as laboratory and residence, to-

SOUTHEAST VERANDA

LOOKING TOWARD SWING BRIDGE OVER FERRY REACH; ST. GEORGE'S HARBOR IN THE DISTANCE.

gether with five cottages, boat and bathing houses, engine house, wharves, etc., all completely furnished and for a price less than the estimated cost of the new laboratory alone. It is fitting in this connection to call particular attention to the generous action of the Government of Bermuda in thus doubling for the present its outlay for the station, in view of the fact that the Hunter Tract may not be immediately disposed of to advantage. All friends of the station are under increased obligation to the government and people of Bermuda for this further evidence of their interest and support.

The buildings at Shore Hills are now being repaired and remodeled for the uses of the station, and it is expected that they will be ready for occupancy about June 15, 1931. There will be in the basement of the main building a physiological laboratory, with accommodations for five or six workers, an aquarium room, a dark room, a cold room and a chemical store room, as well as kitchen, laundry and other rooms for household purposes. On the first floor there will be a large general laboratory, with accommodations for eight or more investigators, and nine private laboratories, all of them supplied with aquaria and running salt water, as well as with gas and electricity; there are also on this floor a living room, a dining room and serving room as well as extensive verandas. The library will be located on the second floor, and in addition there are on that floor eighteen bedrooms, each with an outdoor sleeping porch, and twelve baths. The cottages will afford accommodations for employees and those investigators with families who prefer to live outside

the main building. There are tennis courts and a portion of a golf course on the grounds, a bathing pavilion and an excellent bathing beach. On the whole, no more delightful place for residence and for scientific work can be found in the sub-tropics of the western Atlantic.

The region around Shore Hills is peculiarly favorable for biological and oceanographic work. Some of the best collecting grounds for shallow water organisms are in the near vicinity and there is easy access to coral reefs and heads and to the deep ocean. The station now possesses a small launch and several rowboats, and a larger motor boat capable of being used for deep-sea work will be provided in the near future.

Advantages of Bermuda for Oceanic Research

The Bermudas consist of a chain of some half dozen larger islands and many smaller ones about seven hundred miles due east from Savannah, Georgia, and nearly the same distance south from Halifax, or approximately in latitude 32° N., longitude 64° W. The greater axis of these islands is about fifteen miles from northeast to southwest, and their greatest width is not more than two miles. The total land area is only about twenty square miles, but there is much evidence that the land area was formerly much larger, covering about three hundred square miles. Owing to subsidence and erosion most of this original land is now submerged to a depth of from one to ten fathoms, forming lagoons, sounds and harbors, while only the higher portions of the original land rise above sea level to a maximum height of two to three hundred feet.

The entire Bermuda area is really the summit of a submerged mountain which rises steeply from the ocean floor of the

LIVING ROOM, SHORE HILLS

NORTH VIEW OF SHORE HILLS FROM GOLF COURSE

North Atlantic. On all sides it slopes down more or less precipitously to depths of two miles or more. The core of this mountain is of volcanic origin, the summit is capped by aeolian limestone, and coral reefs surround most of the islands, leaving only a few ship channels into the inner lagoons and harbors.

The advantages of such á site for an oceanic station will be at once apparent. It is possible to live and work comfortably there in a modern laboratory on land and within a few minutes, in relatively small boats and at slight expense, to reach waters of abyssal depths. Only those who have experienced the difficulties and hardships of trying to do delicate scientific work on shipboard or who have some knowledge of the time and expense involved in voyages for the exploration of the deep sea are in a position to fully appreciate the advantages of having that sea brought right to the doors of the laboratory. Johannes Schmidt, who has traced European and American eels back to their breeding places in the ocean deeps south of Bermuda, has said that "Bermuda is like a research ship anchored in mid ocean," but with this significant difference—that it is a ship of great size and stability where one can live and work in comfort every month in the year in a laboratory with all modern facilities.

The greatest area of the earth still relatively unexplored is found in the deep oceans; here occur some of the most extraordinary animals that have ever been seen—animals that live in absolute darkness except for their own luminescence, in ice-cold water, under enormous pressure and in the total absence of green plants. How are they adapted to these unusual conditions? How do they obtain food and oxygen? How do they reproduce, develop and evolve in this strangest of all worlds? Dr. Beebe's studies in Bermuda have demonstrated the wealth of deep-sea life that is there available and the relative ease with which it can be obtained.

Few places in the world are so suitable for the study of the deep sea, and the same is true with respect to the various life zones of the ocean from the floating plants and animals at the sur-

BATHING PAVILION AND WHARF ON RICHARDSON'S BAY

face to the actual bottom. Bermuda lies within that great area of the Atlantic partially surrounded by the Equatorial Current and the Gulf Stream, and by means of these currents and the prevailing winds a wealth of floating life is drifted to its shores. Its land area is so small and it is so completely isolated from the nearest continent that one finds there almost ideal conditions for oceanic research.

In addition to these biological advantages Bermuda offers excellent opportunities for the study of the physics and chemistry of the ocean, the salinity, oxygen content and temperatures of deep-sea water, the surface currents, bottom drift and upwelling of the deeper waters, and the relation of all these to the life of these waters.

Its location makes it a very important post for the study of the weather over the great central basin of the ocean. Colonel Lindbergh has said that Bermuda is destined to be an important station on transoceanic airways, and weather observatories there will be of great importance. An observatory at Prospect Hill has for many years kept daily records of the weather, but recently the Government of Bermuda has established a modern Meteorological Station at Fort George near the Biological Station. Undoubtedly these two stations can cooperate to their mutual advantage, for the Meteorological Station can furnish the Biological Station with forecasts that will be of great service in its oceanic work, and the latter can furnish the former with data on ocean currents and temperatures which are important factors in the genesis of winds and storms.

Because of these and other notable advantages the committee on oceanography of the National Academy of Sciences has recommended that the Bermuda Biological Station for Research be selected as the oceanic sub-station of the Woods Hole Oceanographic Institution. After considering the availability and advantages of the Azores, the Canaries, the Cape Verdes, the Bahamas, the Antilles, the Florida Straits and Tortugas, the report of the committee concludes as follows:

> On the whole, Bermuda seems to the committee the best situation in the North Atlantic

LOOKING NORTH OVER GOLF COURSE FROM SECOND-STORY PORCH

for investigation into the phenomena that are fundamentally characteristic of ocean basins. Its advantages may be summarized as follows:

(1) Its slopes rise so steeply from the sea floor that depths greater than 2,000 fathoms are reached within a few miles from sheltered waters. This would make it possible to carry on serious investigations at great depths with small and inexpensive vessels, and the fact that such work could be done in one-day trips would allow an advantageous unity between field and laboratory work.

(2) The Bermuda cone occupies so small an area that the fundamentally oceanic character of the neighboring waters is not disturbed thereby.

(3) There are two entirely submerged cones close to Bermuda, the "Argus" and "Challenger" banks.

(4) In spite of the precipitous nature of their slopes, the Bermuda reefs enclose a considerable and entirely protected area of shoal water, supporting a rich and varied fauna, and illustrating many phenomena of lime deposition, erosion, etc.

(5) There are several excellent harbors and sites made almost ideal for laboratory purposes by their sheltered anchorage and convenience to the open sea.

(6) All the facilities of the city of Hamilton (also of St. George), with its shipyards, shops, etc., are at hand.

(7) The climate is mild, with no extremes, favoring work the year round, while living conditions are excellent with all the amenities of modern civilization.

(8) Bermuda is conveniently reached by fast steamer from New York, and communication is good the year round.

(9) If the Bermuda Biological Station be reorganized, arrangements could probably be made for the proposed oceanographic substation to occupy part of its property at little or no expense, and this property is admirably located with its own small harbor; proximity to a well-equipped biological laboratory would be a decided advantage, especially in encouraging synthetic investigations involving both the biologic and physical aspects.

(10) The negotiations that have been carried on with regard to the reorganization of the Bermuda Biological Station have shown that the local government and population would welcome scientific activities on the island, which is a consideration of importance.

(5) Bermuda as a Sub-tropical Biological Station

Although Bermuda lies well north of the Tropic of Cancer it has a tropical and sub-tropical fauna and flora. Many tropical plants flourish there, and its coral reefs and heads, although not so rich and varied as many within the tropics, are nevertheless extensive and are the northernmost coral reefs in the

world. This northern location not only brings a sub-tropical fauna and flora near to northern centers of population, but it makes for an equable climate where the summer heat is never so great as to endanger health and the winters are very mild.

The annual reports of the observatory at Prospect for several years past show that the highest temperature recorded was 90.2° F. in September, 1929, and the lowest 44.2° in February of that year. The mean temperatures by months range from 62.9° for January to 80.5° for August, while the greatest daily range was from about 13° in June to 24° in January. As would be expected humidity is relatively high, the lowest for any month being 50 and the highest 90, the mean for all months being about 85.

The great variety of marine organisms of Bermuda has been recorded in the faunal and floral lists published by the naturalists previously mentioned, and particularly by Professor Verrill, but its extraordinary richness and interest can be best appreciated by a visit to the public aquarium at the Flatts, which is probably second to no other aquarium in the world in this respect.

The numerous lagoons, inlets, tidal pools and caves are natural aquaria of great beauty and interest, and the remarkable transparency of the water makes collecting even at considerable depths a visual rather than a blind procedure. Indeed the best method of collecting down to depths of 20 to 30 feet is by means of the diving helmet, and the charm of remaining submerged for some time in water that is comfortably warm and very transparent, and of studying animals in their natural environments is something that has to be experienced in order to be fully appreciated.

(6) Other Attractions of Bermuda

These islands, which were called by early navigators the "Devill's Ilands," and by Shakespeare in "The Tempest" "the vexed Bermoothes," and which later furnished the theme of many a poem and tale of adventure, are now

LOOKING SOUTHEAST OVER CAUSEWAY AND SWING BRIDGE TO STOCKS HARBOR AND ST. GEORGE'S HARBOR, FROM SECOND-STORY VERANDA.

labeled by the cancellation machine of the Bermuda Post Office "The Isles of Rest." And of late it is as a resort, full of historic interest, quaintness and natural charm, that they have come to be better known. There was once a time when Bermuda potatoes and onions and lilies and fruits were their chief products, but the tourist trade has proved more profitable, and where once were cultivated fields there are now great golf courses. But in spite of this, Bermuda has not lost its charm nor been sadly "Americanized." While the tourist trade has created many hotels, developed many sports and has brought to the islands many of the comforts and conveniences of modern life, its people still guard sacredly its eighteenth century simplicity and quaintness. Automobiles are *tabu* and its narrow, winding, shaded roads and lanes are still safe for the pedestrian or the bicyclist.

Bermuda is proud of the fact that it is the oldest self-governing colony in the British Empire and that its Parliament, next to that of Westminster, is the oldest in the empire. The islands are full of historic interest, of old forts and castles and churches, of quaint houses and streets and lanes. St. George is the oldest town in the islands and in many respects the most charming, as it is least affected by modernization. The region about St. George and particularly around Shore Hills is not densely populated and is relatively unspoiled by man. The Biological Station is off the main lines of travel and will afford the seclusion necessary for intensive scientific work, and yet it is only one and a half miles from the town of St. George and not more than one fourth mile from the main highway running the length of the islands. No more delightful place of residence could be found in these "enchanting islands," and certainly no better place for scientific work.

(7) The Bermuda Station a Cooperative International Institution

It has been decided that, for the present, no charge will be made for the use of a table at the station. But since the expenses of maintaining the station will necessarily be much larger than the income now available, it is hoped that many colleges, universities and scientific institutions throughout the world will cooperate in the support of the station by subscribing at least $100 annually for the support of a table or room for a period of two months, or $500 for one year. Such subscription would entitle the cooperating institution to the use of all the general facilities of the station by an approved investigator or research student. It is also hoped that cooperating institutions may provide scholarship funds of at least $200 each to pay the traveling and living expenses of their representatives at the Bermuda Station for a period of two months, since otherwise many worthy young investigators may not be able to avail themselves of the facilities of the station. Such subscriptions and scholarships have already been provided or promised by seven universities or scientific institutions in the United States and Canada, and the widest possible cooperation, both scientific and financial, of individuals and institutions throughout the world is earnestly solicited in order that the Bermuda Biological Station for Research may be truly international in character and may be of the greatest possible service to the sciences of biology and oceanography.

DEVELOPMENT OF THE EGG AS SEEN BY THE EMBRYOLOGIST[1]

By Dr. GEORGE L. STREETER

DEPARTMENT OF EMBRYOLOGY, CARNEGIE INSTITUTION OF WASHINGTON, BALTIMORE

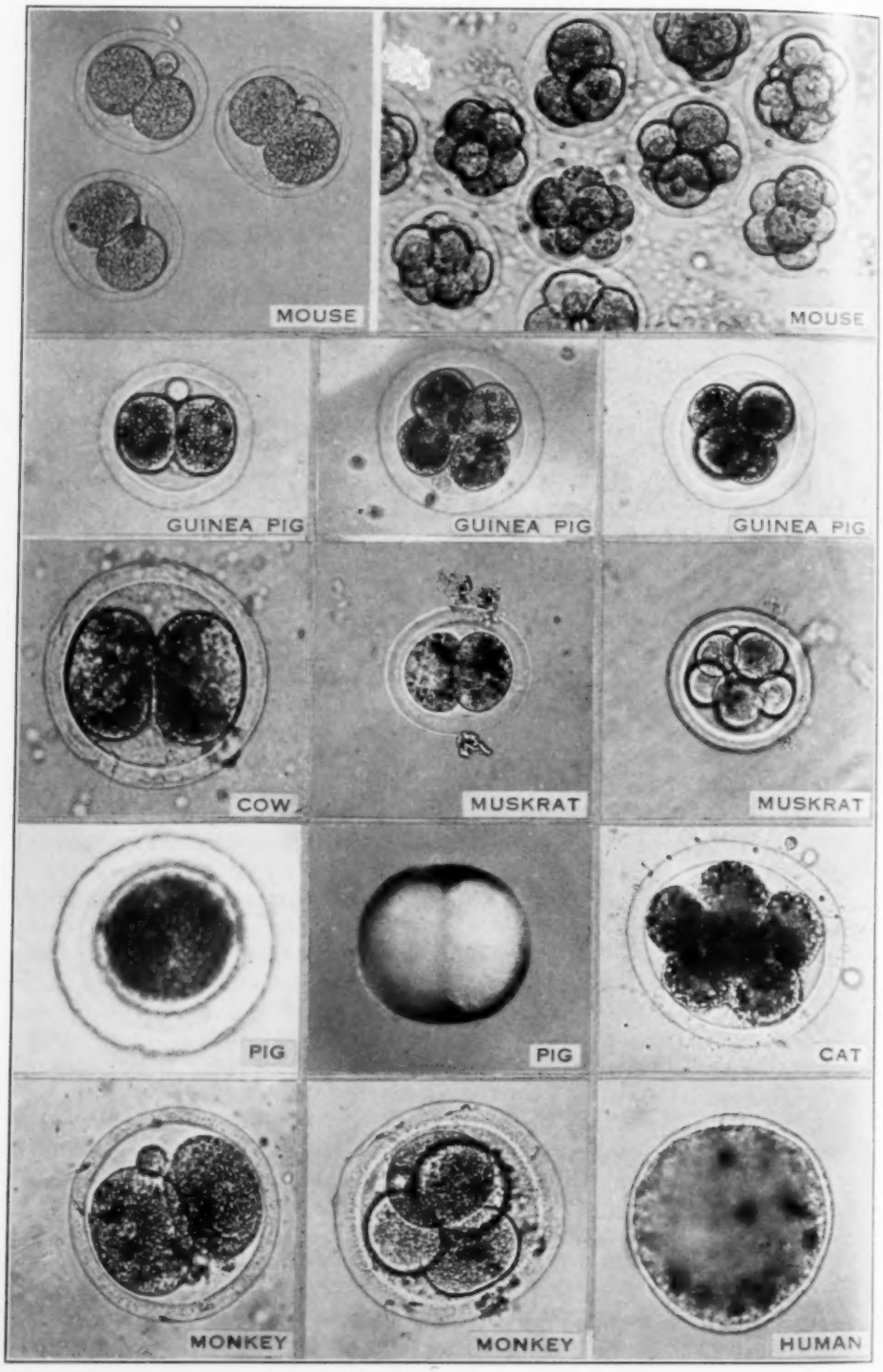
In 1827 a group of progressive business men of Baltimore incorporated the Baltimore and Ohio Railroad. They foresaw that a free pathway to the Ohio River, through its extensive water communications, would mean access to the whole interior of the continent. When they laid their first tracks these early go-getters inaugurated an era in transportation that has had marvelous consequences in the development of America. In that same year (1827) a German professor, Karl Ernst von Baer, discovered the mammalian egg as it occurs in the dog. His observations were published in a monograph which is now rare and is the proud possession of but a few of our American libraries. Though a century has passed one would hesitate to claim that von Baer's discovery has thus far had any consequences whatever on the development of the United States.

In the next one hundred years, however, the relative importance of knowledge of the mammalian egg and knowledge of railroad engineering may be entirely reversed. There are indeed many reasons for thinking that railroads have already attained their best development and are now on the decline, being destined to yield eventually to the competition of other means of transportation. With the mammalian egg the situation is different. We are only just beginning to realize to what extent human welfare is dependent on its structure and its proper performance. It is only in recent years that ways have been devised for observing, testing and experimenting upon such a small object. Enough progress has already been attained, however, to lead one to predict great things of the future. We may never learn all the factors which determine how man comes to be as he is, but some of them appear to be within our grasp. It is my purpose to refer to these things and by means of photographs to show eggs of several different mammalian kinds and to follow the mysterious manner in which they become transformed into embryos, and in turn recognizable animals, and most of all I wish finally to impress upon the reader that the kind of material with which he starts his separate existence is of tremendous importance to him.

The mammalian egg is much simpler than a hen's egg. In the bird there are several auxiliary structures, such as the shell, air chambers, masses of albumen and yolk, which are contrivances suited to the peculiar needs of creatures that develop by hatching. When stripped of all such accessories, as is the case in placental animals, the egg, quite uniformly in both larger and smaller animals, is a very small thing, barely visible to the naked eye. It can be seen if properly illuminated against a black background as a tiny white particle.

By rinsing out the reproductive tract in an animal like the rabbit and by using a delicate glass pipette one can transfer the fertilized eggs to a small glass dish, filled with suitable fluid, and kept at body temperature. Thus installed under the microscope the living eggs can be studied and the stages in

[1] From a symposium on development given at the Carnegie Institution of Washington in November, 1930.


MOUSE
MOUSE
GUINEA PIG
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COW
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CAT
MONKEY
MONKEY
HUMAN

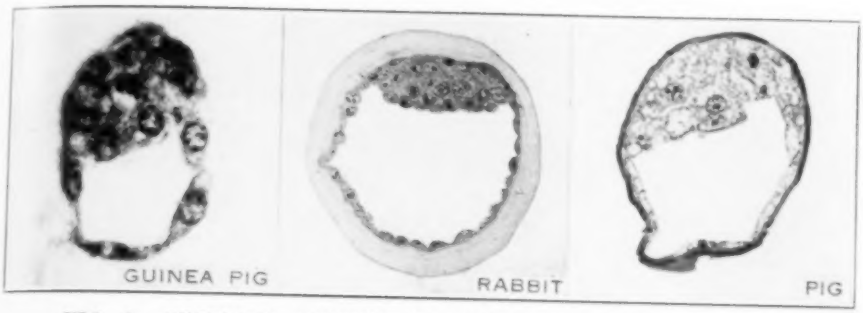


FIG. 2. SECTIONS SHOWING THREE TYPICAL BLASTOCYSTS

BY THIS TIME THE FLATTENED TROPHOBLAST CELLS CAN BE DISTINGUISHED FROM THE MORE PRIMITIVE CELLS OF THE INNER-CELL MASS. THE TROPHOBLAST CELLS ARE ALREADY FUNCTIONING TO THE EXTENT OF PASSING FLUID THROUGH INTO THE CENTRAL RESERVOIR, OR SEGMENTATION CAVITY. FOR THE SECTION OF THE GUINEA PIG OVUM I AM INDEBTED TO DR. N. MACLAREN, GLASGOW.

their development followed step by step for several days. Photographs of living eggs of various mammals which have been studied in this way are shown in Fig. 1.

In studying the recently fertilized living egg, one first of all notices that it possesses a translucent protective capsule. This is a temporary structure which soon disappears, and beyond mentioning its pleasant sounding name—*Zona pellucida*—need not further concern us. Our interest lies in the body that lies within it, as a single cell. If this cell is watched, one presently sees an increasing agitation of its protoplasmic granules, creating a summation of force that eventually terminates in a rending of the cell into two halves. Thus, the single cell, originally composing the egg, separates into two cells and these daughter cells each in turn divide and so on, until in a few days there are many cells.

Now cell division is not to be confused with growth, although it underlies it. In this case it simply means that the single mass of protoplasm with which we started has separated into smaller and smaller units with no increase in total volume. It is known technically as cleavage. One purpose of this appears to be the segregation of the materials of the egg, as a foundation for the division of labor that will be necessary in the more mature organism. Even at the first division the two daughter cells are not identical. One of them is likely to be larger than the other, and the larger of the two is likely to divide sooner, thus showing a beginning difference both in structure and behavior. One must assume that in the division the two halves receive different proportions of the original protoplasmic substances. To say that daughter cells make an uneven division of their heritage is, of course, a crude way to state it. To say anything more precise at the present time would be highly speculative. The embryologists are studying these things assiduously and are talking in terms of attraction and repulsion, surface tension, cohesion and dispersion, difference

FIG. 1. LIVING MAMMALIAN EGGS IN EARLY CLEAVAGE STAGES

ALL ENLARGED 200 DIAMETERS. THESE PHOTOGRAPHS WERE RECENTLY MADE, AND IN MOST CASES THE STUDIES FOR WHICH THEY WERE OBTAINED HAVE NOT YET APPEARED. THE AUTHOR IS INDEBTED TO THE FOLLOWING PERSONS FOR PERMISSION TO MAKE ADVANCED USE OF THEM: MOUSE: W. H. LEWIS; GUINEA PIG, R. R. SQUIER; COW, HARTMAN, LEWIS, MILLER AND SWETT; MUSKRAT, C. H. HEUSER AND R. R. SQUIER; CAT, R. R. SQUIER; MONKEY (*Macacus rhesus*), W. H. LEWIS AND C. G. HARTMAN; HUMAN TUBAL OVUM, W. H. LEWIS.

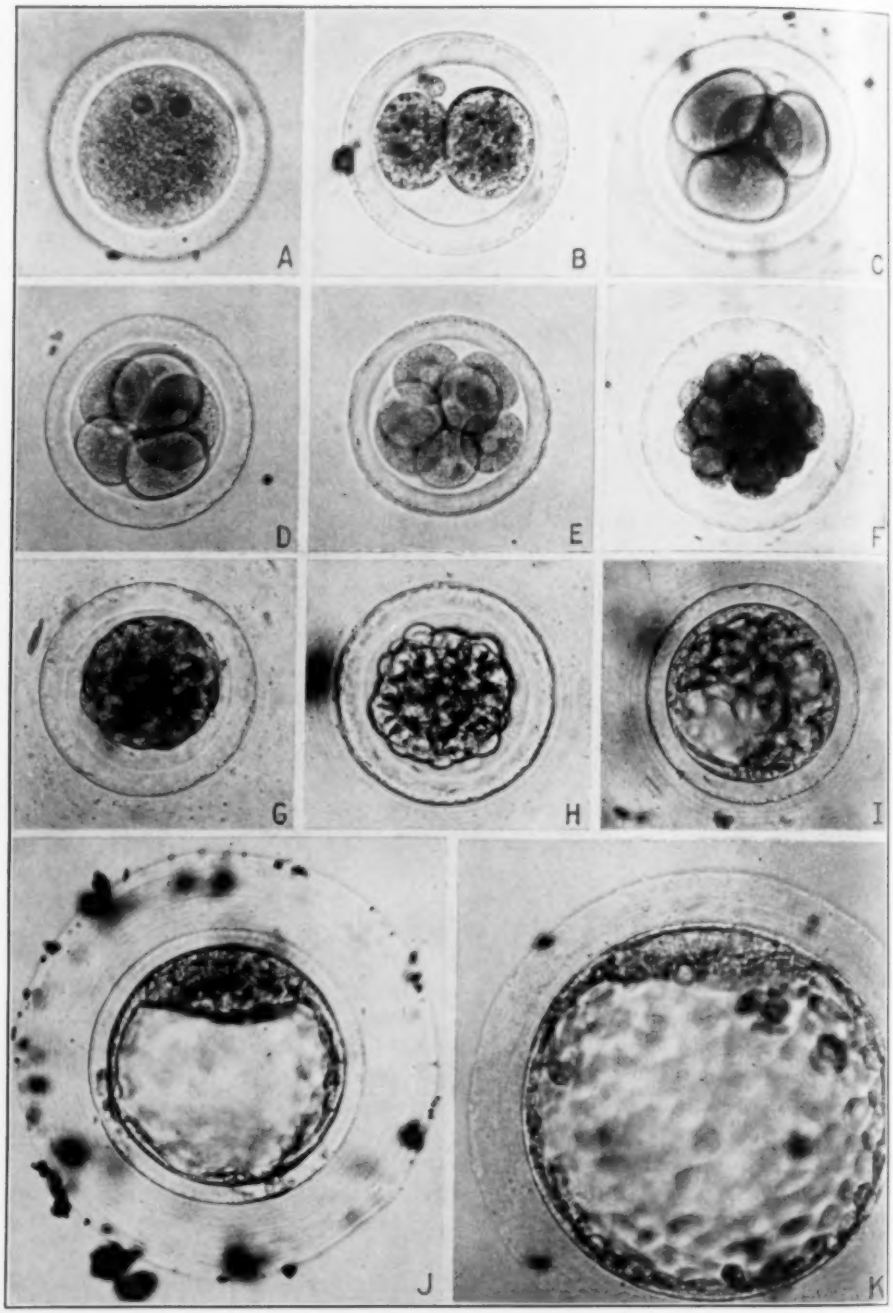


FIG. 3. THE RABBIT OVUM

PHOTOGRAPHS OF THE LIVING EGGS IN A SERIES OF STAGES SHOWING CLEAVAGE, DIFFERENTIATION OF THE TROPHOBLAST, FORMATION OF THE SEGMENTATION CAVITY AND THE DEMARCATION OF THE INNER-CELL MASS, FROM WHICH THE EMBRYO IS FINALLY DERIVED. ENLARGED 180 DIAMETERS. (P. W. GREGORY, "EARLY STAGES IN THE DEVELOPMENT OF THE RABBIT EGG." CONTRIB. TO EMBRYOL. VOL. 21, CARNEGIE INST. WASH., PUB. 407, 1930).

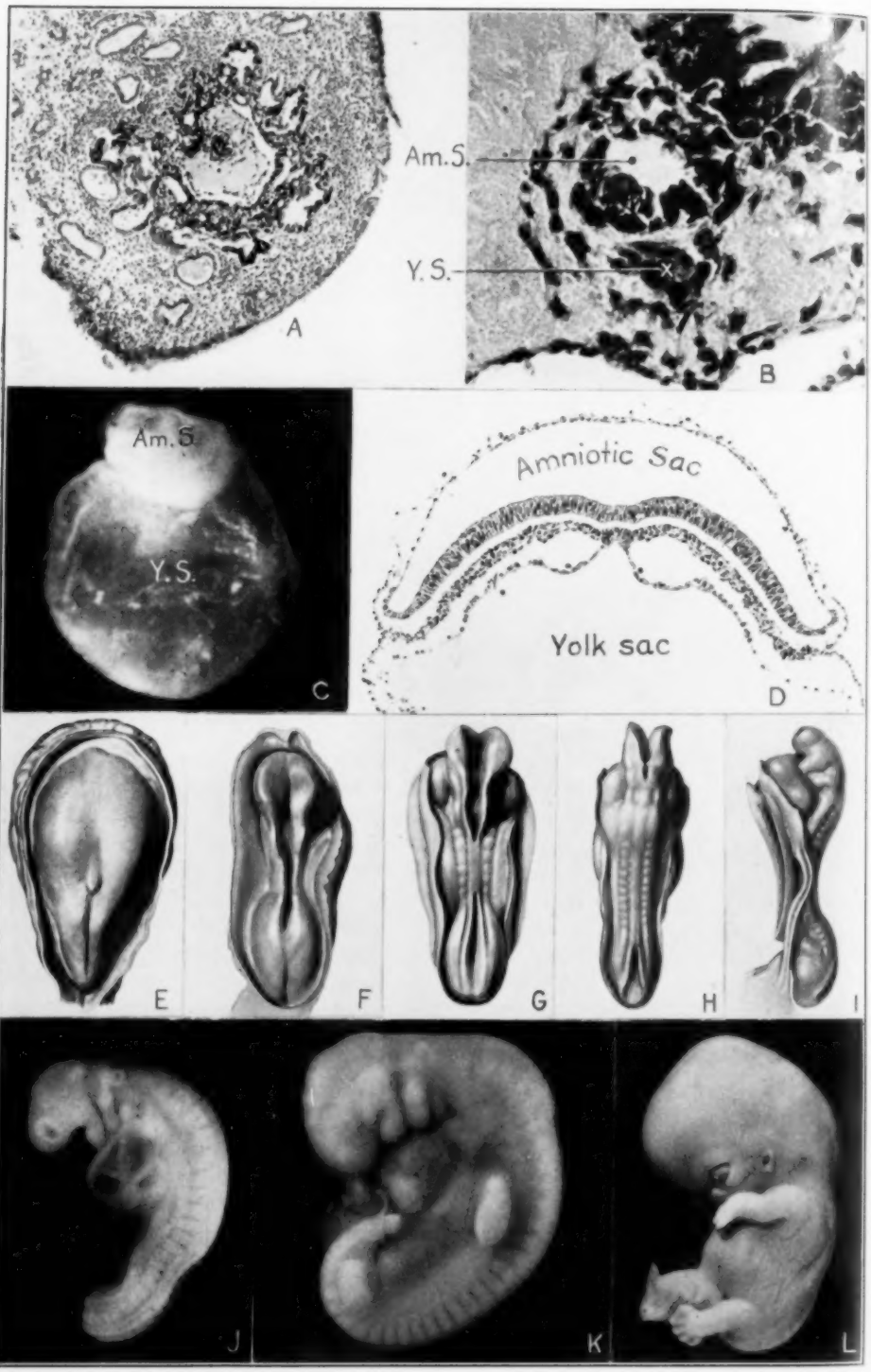
in potentials and electric charges and hydrogen-ion concentrations. In some of these factors, apparently, an explanation of cell division is going to be obtained, and in the meantime it behooves us to await patiently the outcome of their labors.

After a few divisions, the differences between the cells become more pronounced. One finds, for instance, that the material that is to form the implantation-mechanism and fetal membranes, the so-called trophoblast, has already at the 16-cell stage separated off from the material that is to form the embryo proper. The trophoblast is the most precocious part of the egg; its cells divide more rapidly and consequently are smaller and soon begin to show specialization in structure, or as the biologist would say become differentiated. They stand out, in marked contrast to the slowly dividing and more primitive appearing remainder of the egg, the inner-cell mass that is to form the embryo. From then on these two parts of the egg run separate courses and can not change one into the other. The histologist is thus provided with his primal classification for all the subsequent tissue derivatives.

In a sketchy way from what has been said and from Fig. 1 we have seen what the mammalian egg is like. We have seen how it undergoes cleavage into many small cells. We have learned something of the consequences in the way of segregation and differentiation of the precocious trophoblast. Let us pass on to a phenomenon that at this point occurs in the eggs of all placental animals. They become transformed into *blastocysts*, which is another way of saying that the cells of a given egg which originally were clumped as a solid mass become arranged as a hollow fluid-containing sphere. Three typical blastocysts are shown in Fig. 2. Why mammalian eggs become blastocysts can be explained in two ways: Some would say that it is reversion to, or souvenir of, some primitive ancestral type; others, and I think rightly, see in it nothing more than a necessary preparation for the attachment of the egg to the maternal tissues. Certain it is that in all cases the blastocyst wall forms an isolating envelope for the embryo and at the same time it provides an expanded membrane which establishes a large contact with the maternal tissues, favorable for subsequent interchange of fluids between mother and embryo.

As we have already noticed, the trophoblast cells in dividing arrange themselves in a single layer at the surface of the egg, like a membrane, and they also become more mature in appearance. No sooner does this happen than one begins to see lakelets of clear fluid collecting within the egg, the physiological expression of the secretory activity of these newly matured trophoblast cells. As the fluid increases the trophoblast membrane is crowded away from the inner-cell mass and the lakelets coalesce as a common central reservoir. The egg is thus converted into a thin-walled vesicle tensely distended with fluid. It is when eggs reach this stage that they are given the title of blastocyst. Up to this time the egg has become no larger than it was at the outset, but now growth begins and the increase in size of the egg is in proportion to the increase of the fluid with which it is distending itself.

It should be explained that cleavage of the egg into small units and the differentiation of the cells and their arrangements into a blastocyst take place very gradually, so slowly that if watched with the naked eye the changes would not be detected. Were it not for motion-pictures, one would not have been able to speak so definitely about what happens in the egg as I am doing in this paper. It is well known that by


Am.S.
Y.S.
A
B
Am.S.
Y.S.
C
Amniotic Sac
Yolk sac
D
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H
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L

motion-picture photography one can take pictures slowly and then project them rapidly, thus revealing movements otherwise impereceptible. It was a great boon to embryology when it was found that this technique could be applied to the study of microscopic objects like an egg. A triumph in this direction is the Lewis-Gregory film of the developing rabbit egg, which has thrown much light on nature's marvelous way of transforming a single cell into a blastocyst. The more important stages in the cleavage of a mammalian egg and its transformation into a blastocyst are shown in Fig. 3.

Now that the complexities of the blastocyst have been mastered we are in a position to direct our attention to man. It is at the blastocyst stage that our knowledge of the human embryo begins. The youngest known human specimen in which the embryo can be seen is a blastocyst that has just become lodged in the maternal tissues and its age is reckoned at eleven days. All the ova thus far considered have been free blastocysts. This human attached specimen differs in having a great elaboration of its trophoblastic wall. It is apparently by virtue of the latter that the penetration of the maternal tissues is accomplished, technically known as implantation, and throughout pregnancy this trophoblastic shell continues to have a profound effect upon the surrounding tissues. The details of this we will not take up. It is sufficient to know that it forms a protective sac that incloses the embryo and also provides for its nourishment.

Thus far very little has been said about the inner-cell mass. But the last shall not be least. Our belated attention will now be entirely concentrated on these important cells, for they are the ones that form the embryo proper. Lying in the center or toward one side of the egg, they show little sign of change or activity until the trophoblastic shell has provided the proper setting. With that accomplished, the inner-cell mass begins the active assertion of its prerogatives, namely: segmentation, readjustment in position and differentiation. These cells form an embryo in about the same way in the various kinds of mammals with only minor differences. In man, the first thing they do is to arrange themselves as two preliminary vesicles, the *amniotic vesicle* and the *yolk-sac vesicle*. These vesicles become vesiculated in much the same way as the egg managed it, when it changed from a solid cell-mass to a blastocyst. It is a clever developmental device, and we see examples of the same or similar phenomena in the subsequent formation of individual organs. We next find these two vesicles flattening against each other, and where they come in contact they form a bilaminar plate. It is this two-layered plate, or germ-disk, and only this, that forms the embryo. The remainder is accessory and temporary, as much so as the trophoblast.

When the germ-disk is formed and these two layers come together new

FIG. 4. HUMAN EMBRYOGENESIS

A, THE MILLER OVUM, A BLASTOCYST EMBEDDED IN UTERINE WALL, ABOUT 11 DAYS. B, DETAIL OF INNER-CELL MASS OF SAME OVUM, ENLARGED ×250. C, EMBRYO NO. 3,412, ABOUT 14 DAYS, AMNIOTIC SAC ABOVE, TRANSPARENT YOLK SAC BELOW; D, TRANSVERSE SECTION OF EMBRYO NO. 5,960, ABOUT 16 DAYS, SHOWING GERM-DISK WHICH GIVES RISE TO THE EMBRYO. IT CONSISTS OF THE PORTIONS OF THE TWO SACS THAT ARE CONTACT AND THE INTERMEDIATE LAYER THAT FORMS BETWEEN THEM. E, MODEL OF SAME EMBRYO, ×30, ROOF OF AMNIOTIC SAC REMOVED EXPOSING FLOOR OF GERM-DISK. F, INGALLS' EMBRYO, ×28, ABOUT 18 DAYS. G, PAYNE EMBRYO, ×23, ABOUT 19 DAYS. H, CORNER EMBRYO, ×23, ABOUT 20 DAYS. I, ATWELL EMBRYO, ×15.5, ABOUT 22 DAYS. J, EMBRYO NO. 6,097, ×12, ABOUT FOURTH WEEK. K, EMBRYO NO. 1,380, ×8.5, ABOUT FIFTH WEEK. L, EMBRYO NO. 6,202, ×2.5, ABOUT EIGHTH WEEK.

things begin to happen and the developmental tempo speeds up. The two layers are different in character and they interact on each other. This results in the differentiation of new types of cells. As new cells arise new interactions take place, producing other new cells which in turn give rise to further new reactions. In consequence we have not only the new kinds of cells that are provided by segregation and intrinsic differentiation but also those that are derived from the influence of one kind upon another and from other environmental interactions. The structure of our tissues thus becomes progressively more intricate and we begin to speak of organs and definite body parts.

The gross aspects of human embryogenesis are shown in Fig. 4. Starting with the Miller ovum (A and B) one recognizes a blastocyst submerged in the uterine tissue. Its wall is highly elaborated and its cavity is filled with coagulated plasma. In the plasma can be seen the inner-cell mass, especially in B, where under higher magnification its details are better shown. The inner-cell mass forms two main cell aggregations, one of which in Fig. B has already taken the form of a vesicle, the other soon does the same and so we have an amniotic vesicle and a yolk sac vesicle. These can be seen in Fig. C in a slightly older embryo. The thin transparent yolk sac is below and the flattened amniotic sac is above, being opaque, due to its thick floor. D is a transverse section through a similar embryo showing the amniotic vesicle above and a portion of the yolk sac below. Between them a new layer of cells has formed, the mesoblast cells. When the amniotic sac and the yolk sac come in contact, together with the cells that are proliferated between them, there arises a trilaminar plate or germ-disk, and it is this that gives origin to the body of the embryo. At first flat or slightly convex, it becomes converted by thickened longitudinal ridges into a tubular or larva-like body, the successive stages of which are shown in Figs. F to I. This occurs during the third and beginning of the fourth week. There then follow the changes of the second month shown in Figs. J to L. By the end of the second month the principal external features of the body can be recognized and our specimen acquires the status of fetus and is thereafter so designated.

Our briefly told drama of the origin of a new individual is all but finished. There only remains now for it to grow bigger and better and to live happily ever after. But this drama has an epilogue and I am sorry to say a somber one. For the individual doesn't always grow bigger and better, and doesn't always live happily ever after. Eggs are not all alike. We can no longer take the view that an egg is just an egg—with nothing more to be said about it—a kind of biological molecule which is fixed and fast and necessarily perfect at the outset.

There is the common expression "as like as peas in a pod." But the farmer knows that peas in a pod are not alike. He has learned to be very particular about the peas he plants and, moreover, with every kind of seed with which he deals. The butter and egg man prudently notes the size of hens' eggs and whether or not they are fresh. But the poultry raiser needs to know more than this. He has been taught that the hatching quality of eggs is an innate constitutional character, therefore he inquires about their family history. If one takes a clump of frog's eggs and places them under slightly unfavorable conditions, it is found that some of the eggs develop and others do not. By regulating the severity of the environment one can nicely control the number that will fail to develop. The eggs are not alike in their ability to develop in face of hard-

ships. It has been shown in the pig, where there are litters of approximately twelve eggs, all subject to the same environment, that as many as 25 per cent. of the eggs shed are not good enough to reach birth as living individuals. The failures are found in the reproductive tract, arrested in various stages of development in proportion to the degree of their poor quality. A similar incidence appears to be true for man and it is just such specimens that make up a large part of the material that the physician encounters in arrested pregnancies.

The importance of quality of the egg, and of course I include both its maternal and paternal elements, is not limited to uterine life. Whether the infant survives its first year depends in considerable part on the original quality of the egg. If they withstand the usual wear and tear of life until between fifty and sixty years they conform to the actuary's expectation of life at birth—and to the embryologist's expectation of the performance of an egg of average quality. It is only the extraordinarily good egg that is still going strong at 80 years, and we see him (or her) do this in the absence of any exquisite hygienic régime or environmental favor.

We have been speaking of the egg as a whole and have pointed out that it develops and lives in proportion to the vitality with which it is endowed. Good eggs produce hardy long-lived individuals and poor eggs succumb during intra-uterine life, infancy or early years of maturity. The egg as a whole, of course, consists of a multitude of elements and it is the sum and integration of these that determines its fate. Thus, if we would know the quality of the egg we must determine the quality of its parts. As a whole the egg may be a satisfactorily performing mechanism, although certain portions of it are of inferior quality. One finds, in fact, that it is normal for the component elements of the egg to differ among themselves in such qualities as endurance, vulnerability and capacity for growth. One also finds that these differences vary in different eggs and that they are hereditary. Our body is not like the deacon's masterpiece that went to pieces "all at once and nothing first." We are more like the automobile, made of materials of unequal durability, which reaches the automobile graveyard while much of it is still strong and intact. Similarly in the autopsy room we see human mechanisms which are wrecked only because of injury or defect of some single critical organ, for the loss of which the body could not compensate. In numerous unimportant functions the unequal endurance of our various tissues is a matter of common observations. We take it for granted that our teeth are going to yield to decay early. We expect to use spectacles at fifty years. In some families the hair becomes streaked with gray in early adult life. In other families the hair follicles themselves, normal enough in earlier years, degenerate prematurely, with genetic precision, in spite of the most desperate efforts to prevent it. On the other hand, some of our tissues are super-tissues which do their work easily without sign of wearing out and appear capable of a much greater life span than is granted them. Some of our tissues have the power of self-replacement and it would appear possible for such to carry on indefinitely.

These ordinary differences in tissue quality found in the normal individual intergrade with cases where the differences are more extreme. One then begins to speak of them in terms of disease and they become of more serious consequence. Under this heading would come such afflictions as familial retinitis, an inheritable condition in which the retina after functioning normally in youth degenerates in the earlier years of adult life with resultant blindness.

An analogous inheritable deterioration occurs in the organ of hearing, and such families have learned to dread premature deafness. To these might be added many obscure degenerative changes that attack nerve and muscle tissues in middle life. It is also probable that degenerative diseases of the heart and blood vessels are to be explained as well by the constitution of the germ-plasm with which the individual started life (that is, the inherited vulnerability of his vascular system) as by the much blamed overwork, overeating, oversmoking and overdrinking, which in other individuals do not result in a comparable damage.

The Health Department of Baltimore publishes annual mortality tables like other large cities, and there one sees the causes of death tabulated in various ways. In addition to being a black-list of undesirable afflictions, perusal of these tables reveals that deaths from a given disease do not in general occur at a sharply circumscribed time of life but are widely spread over the older age periods. This becomes intelligible if one accepts the point of view that there is an egg-determined life span and an egg-determined vitality of individual organs. Those persons, for instance, who are destined to die of cerebral apoplexy are found to meet their fate

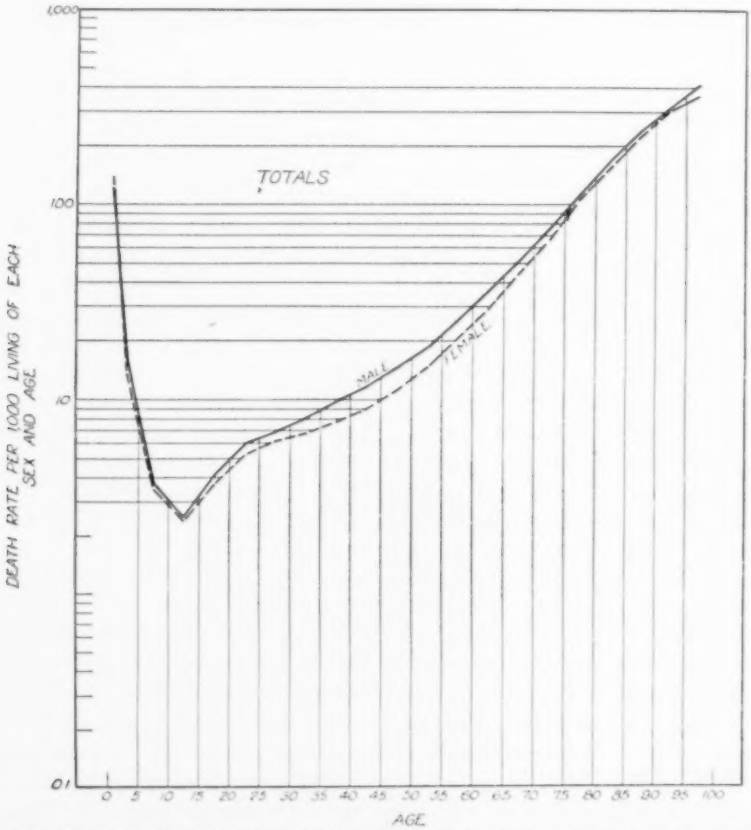


FIG. 5. DIAGRAM SHOWING DEATH RATE AT EACH AGE FOR DEATHS FROM ALL CAUSES TAKEN TOGETHER

(PEARL, "THE BIOLOGY OF DEATH," LIPPINCOTT AND CO., PHILADELPHIA.)

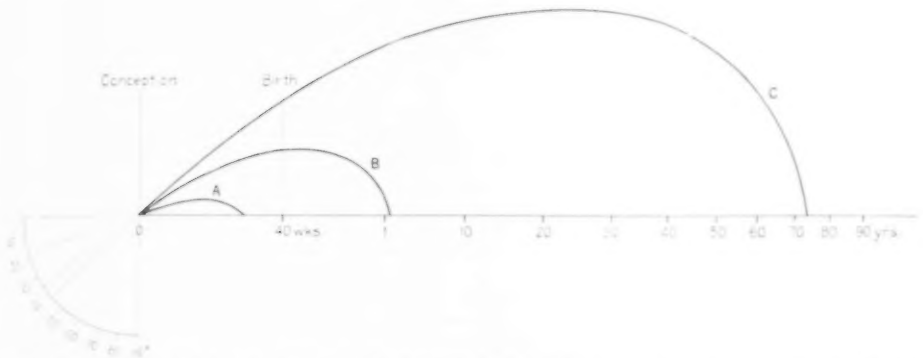


FIG. 6. A SCHEMA IN WHICH QUALITY OR ENERGY OF THE EGG IS REPRESENTED AS A CONTROLLING ELEMENT IN LONGEVITY

LIFE IS SHOWN AS A BALLISTIC CURVE, THE FORM AND SPAN OF WHICH ARE DETERMINED BY TWO FACTORS, NAMELY: THE INITIAL QUALITY OF THE EGG AND THE RESISTANCE IT MEETS IN ITS FURTHER COURSE. IN THE THREE CURVES, CHOSEN AS TYPICAL, IT IS ASSUMED THAT THESE INDIVIDUALS ENCOUNTER THE COMMON WEAR AND TEAR OF EXISTENCE. THE DIFFERENCE IN THEIR LIFE SPAN RESULTS ENTIRELY FROM THE DIFFERENCE IN THEIR INITIAL QUALITY. WERE THE WEAR AND TEAR GREATER OR LESS THE CURVES WOULD BE CORRESPONDINGLY ALTERED. IN SUCH A SCHEMA THE RELATIVE INITIAL QUALITY OF THE EGG CAN BE EXPRESSED IN TERMS OF DEGREES OF THE ANGLE OF PRIMARY INCLINATION.

at various ages from forty to eighty years and more, in accordance with their individual vulnerability to that type of deterioration. The same is found true for malignant tumors, diseases of the heart, cirrhosis of the liver and chronic nephritis. In other words, the age levels in mortality tables are not determined solely by the nature of the diseases but are equally dependent on the extent of vulnerabilities of the individuals affected.

A mortality curve based on a large amount of data showing deaths from all causes is reproduced in Fig. 5. It will be seen that the number of deaths is very high immediately after birth. Falling abruptly, the mortality curve is lowest at about eleven years. From that point it gradually ascends until the oldest ages are all gathered in. This is as one would expect it, except for the excessive infant mortality. Vigorous efforts have been made to reduce the latter and with some success, but it is still a dangerous thing to be under one year old. The reader may be surprised to learn that 10 per cent. of all deaths in Baltimore last year (1929) were recruited from this age-group, and in former years the proportion has been nearer 20 per cent. This large infant mortality, however, can be understood if one remembers the change in living conditions the infant meets at birth. In the prenatal state he enjoys highly favorable arrangements in respect to temperature, respiration, food supply and absence of infections; and even fetuses of poor quality can make a "go" of it. But with the advent of birth the less well-endowed babies are not able to survive and nature's first great sorting of the fit from the unfit takes place with its terrible toll.

The traditional concept of disease and death portrays for us a grim reaper who, stalking about with scythe and hour-glass, embraces with his bony arms the unwary laborer at his task. Death has been conceived of as a horrid person who to some extent can be eluded through magical charms, cleverness or divine aid. The classical way of life (Fig. 7) is a uniform procession from infancy to tottering old age, any de-

parture from which is abnormal. In more recent times disease, for the most part, became the consequence of various evil microscopic organisms or injurious viruses, and when all these were eradicated from the surface of the earth universal well-being would prevail. We still to-day think of germs as evil, but other factors have entered. We have learned that the same germ is not equally injurious to all persons. The campaign on their complete eradication is slackening and the problem has been shifting to the matter of individual resistance. Instead of the traditional concept of life of Fig. 7, a new schema must therefore be substituted in which the span of life is determined by two opposing factors, namely, the initial energy or quality of the egg and the resistances it subsequently encounters.

It is not my intention to proceed further with the complicated problem of disease or with the various factors that underlie body defects and death. But I hope some impression has been conveyed as to what man is like at the beginning and that my thesis has been made clear that this tiny egg contains not only his possibilities in the way of morphological characteristics and mental attainments but also determines what endurance he is to have in meeting the various vicissitudes of life that are lying in wait for him. Let us hope that he is a good egg!

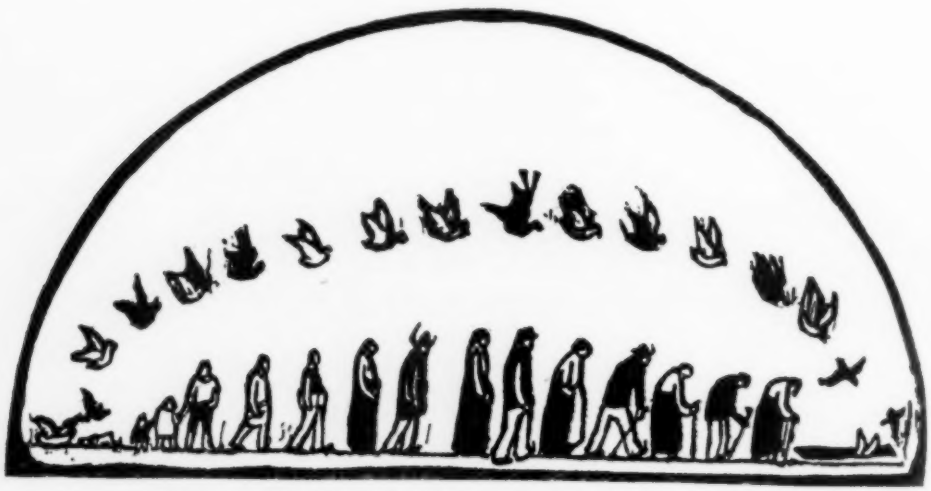


FIG. 7. THE WAY OF LIFE: BY FRANCESCO GAMBA
REPRODUCED IN THE *Baltimore Sun*, OCTOBER, 1930.

SCIENCE IN THE LIVE-STOCK INDUSTRY

By Dr. J. R. MOHLER

CHIEF, BUREAU OF ANIMAL INDUSTRY, U. S. DEPARTMENT OF AGRICULTURE

THE influence of science and invention in the industrial world is so familiar that there is a tendency perhaps to associate scientific discoveries principally with developments in that field. Revolving wheels, electrical wires and new commodities confront the American public constantly. Hence it is natural that mechanical, electrical and chemical advancement should attract particular attention.

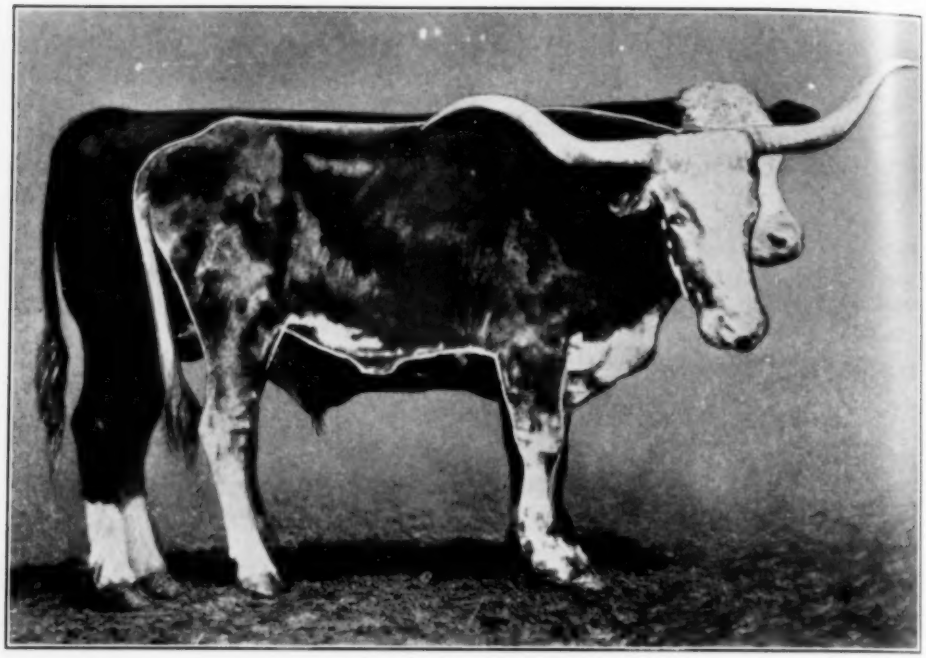
SCIENCE AIDS NATURAL PROCESSES

The forces of science are also operating steadily and in a most interesting manner on life itself and the effects are especially visible in our domestic animals. Live stock in the United States are much more numerous than the human population, and since their breeding, feeding and general care are under close human control, the effects of scientific methods are readily seen to be on a large scale.

Without the knowledge which science has given producers and distributors of live-stock products, the present supply would be materially less, of lower quality and probably of greater cost to consumers. Without scientific knowledge the delivery of pure, safe milk in large cities would be severely restricted; the supply of desirable wool and leather would be uncertain; and ham and eggs would doubtless be found less often on our breakfast tables. Among the devel-

A TON LITTER,

MEANING THAT THE PROGENY OF ONE SOW WEIGHED TWO THOUSAND POUNDS OR MORE AT 180 DAYS OF AGE. THIS LITTER EXCEEDED THE REQUIREMENT, ATTAINING A WEIGHT OF 2,910 POUNDS.



COMPARISON OF LONGHORN STEER

OF THE TYPE COMMON FIFTY YEARS AGO, WITH AN IMPROVED BEEF ANIMAL OF TO-DAY.

opments largely responsible for improved conditions in animal production are methods expressed through veterinary science, refrigeration, pasteurization, meat inspection and numerous related activities.

Unlike human beings who protect their health by adequate housing, sanitary sewage disposal, cooking of their food, use of screens and other familiar safeguards, domestic animals are constantly exposed to bacterial and parasitic dangers. Besides, the attention given to their health and welfare is determined largely by their commercial value. A stock owner is unlikely to spend more on the treatment of an animal than the animal is worth. In fact, he could not afford to do so as a general practice. Hence the profitable production of our domestic live stock involves painstaking methods to prevent animal ills as well as exceptional efficiency in feeding, housing and general care. Fortunately, scientific study has developed many satisfactory methods of preserving live-stock health and improving animal types.

Research Solves Live-stock Mysteries

A half century ago many mysterious losses beset the business of producing domestic animals. In parts of the Southwest, cattle and horses were observed to go "crazy," and in the intermountain region large numbers of sheep apparently in the best of health one day would be found dead the next morning without visible signs of the cause.

Cattle owners in the South were perplexed by the "bloody murrain" which killed thousands of cattle and reduced others to an unthrifty, stunted condition. The number raised to market condition was, in large degree, a matter of chance. Various economic factors likewise were involved and in some in-

stances state and local legislation was a material factor, as in the case of laws to restrict the ravages of sheep-killing dogs.

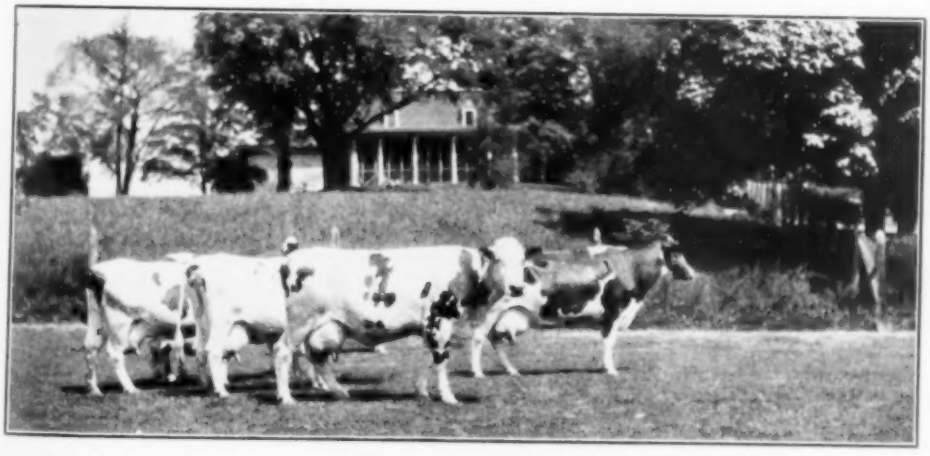
In those days a visitor to the farms and ranches of the United States observed materially different types of animals than are seen to-day. Cattle had larger heads, longer horns and smaller bodies. Besides, they required a much longer time to reach market size and condition than they do to-day. Hogs were faster on foot but slower in growth and besides were at the mercy of the then unchecked scourge, hog cholera.

As time went on, stockmen learned that in dealing with many specialized problems long experience counted but little. Personal courage and aggressiveness could check the inroads of cattle rustlers and other visible enemies, but were powerless against the elusive contagion of animal disease. This condition resulted, in 1884, in the establishment of the Bureau of Animal Industry in the United States Department of Agriculture. The same or similar problems also stimulated research and experimentation in various state institutions and were largely responsible for the development of agricultural experiment stations.

Animal Diseases Brought under Control

It is true that "book farming" did not appeal to many veteran stockmen at first, and some of the scientific explanations and proposed remedies for various troubles fell on unbelieving ears. When the Bureau of Animal Industry announced that the bloody murrain was a fever carried and transmitted by cattle ticks, there was skepticism, and when the work of eradicating ticks by dipping cattle in an arsenical solution of tested strength began, there was opposition, often of violent nature. Dipping vats were destroyed by lawless persons who objected to the innovations which they felt were being forced upon them. But time gradually demonstrated the soundness of the scientists' recommendations. In the case of tick fever, 82 per cent. of the territory formerly infested has been freed of the disease by systematic dipping of ticky cattle. The average progress has amounted to about 25,000 square miles annually.

The discovery by the same bureau of



PORTION OF DAIRY HERD OFFICIALLY ACCREDITED AS FREE FROM TUBERCULOSIS.

WOOL IN THE MAKING.

THE PRODUCTION OF FINE WOOL HAS BEEN MATERIALLY AIDED BY ANIMAL HUSBANDRY RESEARCH.

a preventive serum for hog cholera restored confidence in swine production and the manufacture of the serum is now an extensive industry. This safeguard to hog health is especially valuable in regions, such as the Corn Belt, where swine are raised in large herds and where an outbreak of disease among susceptible animals would have far-reaching and ruinous consequences. As a further help to hog-raisers, correct methods of using the preventive-serum treatment are demonstrated by veterinarians of the bureau who are especially trained in hog-cholera-control work.

During the last twelve years the Department of Agriculture, cooperating with the states, has waged an aggressive war likewise against bovine tuberculosis. As a result the average extent of tuberculous infection among cattle has decreased from more than 4 per cent. to 1.7 per cent. In approximately 1,100 counties which have been especially energetic in the systematic testing of cattle within their borders, the infection is known to be less than one half of 1 per cent. Scientific discovery, utilized in a definite plan of field operations, has made this kind of progress possible. In recent years the work of eradicating tuberculosis has been extended likewise to swine and poultry, with encouraging results.

Utility of Live Stock Is Increased

Simultaneously with the conquest over various animal ills, investigators in live-stock breeding have demonstrated how stockmen may control the size, form and general appearance of their animals through knowledge of the laws of heredity. This knowledge is now recognized as a practical means for increasing the utility value of domestic animals as well as for controlling color, horn development and other qualities. Thus, through knowledge of animal breeding, the modern stockman has virtually become a sculptor in living flesh and the most able breeders are virtually designers of the latest models of domestic live stock. Through breed associations and live-stock shows and expositions, the types of animals considered most desirable for present needs are publicly recognized and awarded prizes. The types naturally vary, depending on

the purpose for which raised. Accordingly, there are well-marked differences between cattle for beef and dairy purposes, horses for light-harness and draft service, and between sheep intended primarily for the production of wool as contrasted with the so-called mutton breeds.

Besides aiding live-stock producers in safeguarding their investment and increasing the usefulness of their animals, scientific research continues to make still other valuable contributions. It has furnished a simple and accurate test for the fat content of milk and investigators are now conducting intricate studies on the quality and palatability of meat. Research has determined, for instance, that the hatchability of eggs is influenced by such factors as inbreeding of the parent stock and by the quantity of animal protein in the feed of hens, as well as by conditions of incubation.

Science likewise has furnished the background for the extensive federal meat-inspection service which supervises all processes in the slaughter of about 75 million head of stock annually and the handling of their meat. In this work veterinarians, pathologists, chemists and sanitary experts all contribute to the highly efficient system that is now accepted as a necessary part of modern living.

Considering that live stock have been kept by man for fully 50 centuries, it is indeed noteworthy that the last 50 years have witnessed the most outstanding progress in breeding and raising domestic animals, safeguarding their health and welfare, and finally utilizing their products.

Shows Opportunities for Further Progress

Within the same period great improvement in breeds and types has likewise occurred. Records of production

THE IMPROVEMENT OF POULTRY.

Poultry, as well as the larger farm animals, are being improved by selective breeding combined with scientific methods of feeding, care and housing.

by individual animals have steadily increased. It is not unusual for dairy cows to produce more than 20,000 pounds of milk annually, for a litter of pigs to weigh more than a ton at six months of age, or for a well-bred hen to lay more than 250 eggs in a year. All these figures greatly exceed ordinary performance and point to goals that are readily accessible by the means that modern knowledge has made available.

Though we have cause to be grateful for the contributions of research to our welfare, a true appraisal of science in the live-stock industry shows, however, that Nature is still our greatest benefactor. No investigator has thus far evolved a fully satisfactory substitute for meat, milk, leather, eggs, and scores of other animal products. And the abundance of these products in daily use indicates preference for them to many articles resulting from purely artificial processes. Thus we are richly endowed by having, in the animal resources at our disposal, a plastic living material that we can adapt to our changing needs.

Formerly, in the wild state, animals were both a source of danger to mankind and a somewhat uncertain resource. But under domestication and with the increasing knowledge that science has provided, the lower animals have become one of the most valuable assets of our civilization.

LEPROSY IN THE UNITED STATES

By Dr. WILLIAM W. FORD

PROFESSOR OF BACTERIOLOGY, SCHOOL OF HYGIENE AND PUBLIC HEALTH, JOHNS HOPKINS UNIVERSITY

THE history of leprosy has always been of peculiar interest to members of the medical profession because of the important problems which have arisen in regard to its causation and mode of spread. No less interesting has it appeared to the non-medical, since references to it abound in Biblical and secular literature and many an individual, doctor, nurse, priest or pastor has devoted years of self-sacrificing effort to the care of the unfortunate lepers, in spite of the hardships which had to be endured and in the face of a possible transmission of the infection from the victims of the disease. Religious orders of nearly every denomination have been active especially in their care, and in many regions it has been to the inspired members of these orders that the lepers have looked for attention during life and for spiritual consolation in their closing hours. The life and death of Father Damien, the Belgian Catholic priest who went to the leper colony in Molokai and who eventually contracted the disease and died from it, have been immortalized by Robert Louis Stevenson.[1] Books of travel and romantic literature are full of references to leprosy. In Richard Burton's "Ultima Thule," which is an account of his visit to Iceland in 1872, there is an excellent description of the disease, and the picture of leprosy given by Lew Wallace in "Ben Hur" has aroused the compassion of countless readers. Of especial interest is the extent to which lepers and dramatic incidents connected with them have been depicted by great artists of the past. One need mention only Donzello's "Saint Martin" in the National Museum in Naples, the "Job with Wife and Friends," by Lucas Cranach, or by an artist of the Cranach School in Frankfürt a.M., the "Job," by Albrecht Dürer in Frankfürt a.M., the "Saint Elisabeth with a Leper," by Holbein in Basel, and the "Saint Elisabeth," by Murillo in Madrid, to indicate how frequently lepers appear in the great canvases of the old masters.

Modern knowledge of disease, and especially the study of the origin and spread of the type which is called contagious or communicable, has taught us much about leprosy and we now realize that many of the ideas formerly entertained in regard to it were erroneous. We know that leprosy is not violently contagious, does not pass rapidly or easily from person to person, apparently requires a long period of exposure and that its spread in a community is determined by many factors in addition to the presence of a leper. Yet the fear of leprosy which has come down to us through the passing of 2,000 years and more is still entertained by many and at times stimulates a cruelty and persecution which are reminiscent of the Dark Ages.

Leprosy, also called *Leontiasis, Satyriasis, Elephantiasis Graecorum, Lepra Arabum, Aussatz* in German and *Spedalsked* in Norwegian, has been known from early times. It is now believed that the word "leprosy" as used in the Biblical sense was a generic term covering various sorts of skin disorders which rendered the afflicted individuals "unclean" and disqualified them for the worship of Jehovah. The descrip-

[1] Robert Louis Stevenson, "Father Damien: An Open Letter to the Reverend Dr. Hyde of Honolulu."

tion found in very early Japanese medical writings probably refers to another ailment, but the disease now regarded as leprosy was apparently recognized in China in the twelfth century before Christ. The leper "whiter than snow," however, was not a victim of leprosy but rather of a totally distinct skin disease now called leucoderma. While the ultimate origin of the disease is masked in impenetrable obscurity, satisfactory accounts of it were given by Aretaeus in the first century of the Christian Era and in the second century Galen described it from the cases he saw in France and Spain. It was known in Egypt and India, as well as in China, long before the Christian Era and was wide-spread in all the countries about the Mediterranean Sea. Carried westward by the Roman soldiers and traders when the power of Rome was at its height and later disseminated by the Crusaders, it spread throughout Europe and became a scourge in the Middle Ages, reaching France, Germany, England, Ireland, Scotland, the Scandinavian Peninsula and many of the outlying islands of the North Sea. Gradually the disease came under control, probably in large part as a result of the strict isolation of the afflicted, an isolation which we now regard as cruel and unnecessary. With a practice based on the Mosaic laws as laid down in the book of Leviticus the lepers were driven away from families and friends, forced to live in out-of-way, desolate places, to subsist largely on charity, their food and clothing procured by stealth, and compelled to announce their presence by crying "Unclean," shaking a rattle, ringing a bell or blowing a horn. Indeed in some particulars their persecution went far beyond this, for sometimes their property was confiscated by the state, when they were people of means, and usually the civil authorities cut them off from human society when the disease was discovered by medical inspection (Lepraschau), so that they were legally dead from that time on. But it must be remembered that these cruelties were perpetrated in a cruel age when capital criminals were hanged, drawn and quartered, when political crimes were expatiated by breaking on the wheel, when men, women and even children were burned in frenzies of religious zeal, and when petty malefactors were stretched and jerked upon the scaffold so that the joints of the long bones were dislocated and they became hopeless cripples. One likes to think rather of the consideration and kindness with which lepers were treated in the period of awakening enlightenment at the end of the Dark Ages when, after the example of Basil the Great at Caesarea, over 20,000 leper homes were established in Europe and where the leper was at least sure of food, lodging and a place in which to die.

As a result of the stringent regulations and the segregation practiced in Europe during the Middle Ages, the number of cases diminished with considerable rapidity and the disease died down except for isolated instances appearing from time to time over a wide area. It persisted in several places which are of interest to America, for foci of leprosy remained in Brittany and Normandy, in the Scandinavian Peninsula, particularly in Norway, and in Iceland. In the south, leprosy was common on the West Coast of Africa where it is still prevalent, as well as on the East Coast.

In the area now embraced in the United States leprosy appeared quite early in several regions. It was reported in Louisiana in 1784 and is said to have been brought by Spanish settlers. It got a foothold, however, among the families of French origin who came from a part of France where leprosy was endemic. Ever since that time the disease has been found in

Louisiana and has been in general limited to French families. In 1900 there were 125 reported cases, but since then the number has decreased gradually but definitely. It has shown little tendency to spread to other elements of the population. The lepers were originally cared for in their homes or admitted to some of the hospitals in New Orleans. Eventually the state established a leprosarium at Carville. With the settlement of Minnesota, leprosy was introduced by the colonists from Scandinavia, chiefly by the Norwegians coming from a country where the disease was endemic. The lepers were in general isolated and looked after by their families, but the facilities for their care and treatment were so inadequate and the lot of the unfortunate leper so unhappy that Dr. Bracken, state health officer, came to their aid and by his courageous example did much to allay the popular fear of the disease. Through Dr. Bracken and other health officers interested in leprosy the United States government was induced to take over the Louisiana State Leprosarium, which thus became a National Leprosarium. Thirty years ago there were about 50 reported cases in Minnesota. Since then the disease has constantly diminished in frequency, partly of course because many of the lepers are transferred to Carville. At the present time there is but one active case in Minnesota, cared for with strict isolation under the state department of health. In Minnesota leprosy has shown no tendency to spread from the colonists who brought the infection with them to other elements of the population, and the state can now be said to be free of the disease.

In Canada the history of leprosy is especially interesting, but the facts in regard to it are somewhat difficult to establish. Foci have existed from early times among the Acadians in Nova Scotia and New Brunswick, among the French Canadians in New Brunswick and in a few spots elsewhere. Many conflicting stories about its origin in Canada have been current from time to time, sometimes to the effect that the disease was carried by the Acadians to Louisiana after their expulsion from Nova Scotia in 1755 and again that leprosy was contracted by the Acadian families during their sojourn in Louisiana and taken back by them to Nova Scotia. The origin of leprosy in Canada has recently been investigated with care by Dr. John H. Heagerty, of the Canadian Department of Health.[2] He states that it first appeared in official records as found in Tracadie in the Province of New Brunswick in the year 1815, in a French Canadian family coming originally from Normandy, in which it was introduced by leprous Norwegian sailors. This story has been denied and Heagerty points out that there is some evidence to show that leprosy was present from early times in the district known as Acadia, which comprised Nova Scotia and a part of New Brunswick, including Tracadie. A lazaretto was established at Tracadie in 1815 and from that time till 1924 319 lepers were admitted, chiefly from New Brunswick and Nova Scotia. In Canada again, the disease has tended to limit itself to well-defined groups of people, but has appeared among families of Scotch, English and Irish descent, as well as among those of French origin. At the present time, the leprosarium supported by the Dominion of Canada at Tracadie, New Brunswick, on the Gulf of St. Lawrence, houses 10 lepers, of whom 4 are French Canadians, 3 Russians, 1 French-Scotch, 1 English and 1 Chinese.[3] Leprosy in eastern parts of Canada is thus reduced

[2] John J. Heagerty, "Four Centuries of Medical History in Canada."

[3] Personal communication from Dr. Norman M. Harris, of the Department of Pensions and National Health, Dominion of Canada.

to a small number of cases and the disease is gradually disappearing.

Finally, both in the United States and in Canada, cases of leprosy have been somewhat frequent among the Chinese resident in the cities along the Pacific Coast such as San Francisco and Vancouver. The cases occurring in the United States are now sent to Carville, while the Dominion of Canada maintains a small leprosarium at Bentinck Island, British Columbia, within three miles of the quarantine station at William Head. This leprosarium now harbors nine Chinese lepers and is maintained primarily for this group, those of other nationalities being sent to Tracadie.

In addition to these well-marked foci of leprosy in North America, sporadic cases occur from time to time, chiefly among inhabitants of Louisiana, Florida, Texas and Mississippi, where the disease may still be regarded as endemic. Occasionally cases appear in other states such as Massachusetts,[4] New York, California, Missouri, New Jersey and Maryland. In these areas the advanced cases are now sent to Carville, while the non-infectious are cared for by state or city departments of health.

From this brief review two facts are quite clear. One is that leprosy is definitely decreasing in the United States and Canada. The other is that it presents no menace to this country. Both in Canada and in the United States, the cases are recognized early, advanced cases are sent to suitable institutions, and the disease shows no tendency to spread out of well-defined areas. Leprosy then can not be regarded as a public health problem of any importance in these countries. To the south of us, in Mexico, the condition is not so favorable, since cases of leprosy are fairly frequent, especially in Mexico City. This affects the United States only when Mexican laborers in this country develop the disease, in which event they are either sent back to their homes or committed to the national leprosarium.

At the present time the United States government twice a year gathers the lepers found on the Pacific Coast in special trains and transfers them to Carville. From 1894 to 1928, 718 have been admitted to Carville and 300 cases are now under treatment there.

With the acquisition of the Hawaiian Islands (Sandwich Islands) and the Philippines in 1898 the problem of this disease took on a somewhat different aspect for our government. In the Hawaiian Islands, a population of about 100,000, with a large amount of leprosy, was added to our numbers. Here the disease was introduced about the middle of the nineteenth century, apparently by the Chinese. The infection spread rapidly among the Hawaiians and reached such alarming proportions that the native government, in 1864, established a leper settlement at Molokai,[5] the administrative control of which was assumed in a general way by the United States with the annexation of the Islands. The number of new cases in Hawaii has varied greatly from year to year, reaching 558 in 1888 and falling to 23 in 1908. The average yearly number is now about 50, and the disease has been found chiefly among the people of native blood. In 1890, 1,230 lepers were in isolation. Since then the number has decreased considerably and in 1928 had fallen to about 700.

In 1898, when the Philippine Islands were taken over by the United States, we acquired a new population of 7,000,-

[4] Massachusetts formerly maintained a state leper colony on Penikese Island, where a few cases were segregated. In 1922 this station was given up, the active cases being transferred to Carville.

[5] See "The Public Health Aspect of Leprosy," by Dr. George W. McCoy, *Boston Medical and Surgical Journal*, 1917, Vol. 126, No. 2, pp. 43–48.

000, now increased to about 13,000,000. Leprosy is a common disease among the inhabitants of these islands. It is said to have been brought to the Philippines by a boat-load of 150 lepers sent there by the Japanese about 1750, but it must be remembered that leprosy was still endemic in Spain at that time and that Spanish colonists may well have carried the disease to the Philippines, just as they probably did to large areas of South America, Central America and Mexico. At any rate leprosy spread rapidly among the native Filipinos and soon became one of the prevalent ailments. It is estimated that there are no less than 200,000 lepers in the Islands at the present time, spread among all the native tribes, among the Japanese and Chinese. A detention service is maintained in Manila in the San Lazaro Hospital, but the majority of the lepers are sent to a leper colony at Culion Island, a remote spot where between 5,000 and 6,000 cases are now housed and treated. Other hospitals on the island look after a great many in addition. Recently, under the Manila Board of Health and Leonard Wood Memorial Association, treatment stations for leprosy have been established at various points and a determined effort is being made to combat this scourge. Research is fostered, experts are trained, and correct information spread throughout the land.

Finally a word or two may be said about the purely medical aspects of leprosy. It is in general one of the saddest of human spectacles, chiefly because of the outspoken aspect of the lesions, but partly from the hopeless character of the infection. It appears in two main forms, the *nodular type*, in which nodules develop beneath the skin in various parts of the body, and a *macular-anesthetic* type, in which eruptions occur on the surface and in which extensive areas are rendered *anesthetic* with loss of sensation. The nodules may become large and deforming, the face may become so changed that resemblance to the human facies is almost lost, the swellings may break down and ulcerate, giving rise to foul, ill-smelling masses. The eyes are affected and sight is frequently lost. Ulcerations occur in the nose and mouth, and the larynx may be involved, causing extreme shortness of breath. The anesthetized parts are so easily injured that fingers and toes may actually slough off almost without the knowledge of the patient. Altogether the advanced leper may present about the most horrible of human monstrosities. The disease is essentially chronic, and the period from the outbreak of symptoms to the fatal termination may last for years. This chronicity of leprosy, with the prolonged period of contact necessary for transmission, its long incubation period, its slow development from the period of recognizable lesions to its eventual termination and the leisurely spread in the population is well pictured by Sudhoff,[6] formerly professor of the history of medicine in Leipzig. From the early days of bacteriology investigations on the cause of the infection have been carried out in various parts of the world. There can be little doubt that the etiological agent is an organism described as the leprosy bacillus by Hansen in 1880. This organism closely resembles the tubercle bacillus, the cause of tuberculosis, but it has never been definitely cultivated outside the body on artificial media. Nor has leprosy ever been transmitted to the lower animals. The presence of the leprosy bacillus is diagnostic of the disease, however, and is our chief means of assured recognition. Leprosy is transmissible from person to person and never appears spontaneously in a community free from it. Prolonged contact with a case seems to be necessary

[6] Karl Sudhoff, "Epidemiological Rules of the Past," in "Essays in the History of Medicine," translated and edited by F. H. Garrison.

to transmit the infection, the kind of contact which comes from living in the same house, eating from the same utensils, washing the clothing of lepers over long periods. The disease is not hereditary, and children of leprous parents, removed from them immediately after birth, do not develop the infection. The incubation period, that is, the time between exposure and the outbreak of definite signs of the disease, is long and subject to great variations. It may be as short as two years and as long as ten years. Various factors seem to play a rôle in the propagation of leprosy, that is, in the origin of epidemics, and these factors are by no means clearly understood. At times it seems to spread in family stocks. Thus Hopkins and Denny,[7] in their careful study of leprosy in the national leprosarium at Carville, have pointed out a distinct familial tendency in Louisiana, in that leprosy appears in closely related families. Again it seems to spread in racial stocks, as in the Hawaiian Islanders, but McCoy believes that this is not necessarily a racial tendency but may result from habits of living or other factors. Climate has been thought to influence leprosy, but it may become epidemic and remain endemic both in the tropics and in cold countries like Scandinavia and Iceland. It is doubtful whether food is a factor, although years ago Jonathan Hutchinson pointed out that leprosy was apt to occur in people who subsist largely on fish. At the present time we can say that leprosy spreads and remains endemic in certain countries like China, Japan, the Philippines, the Hawaiian Islands, and dies out in Northern Europe and in North America. Certainly in the United States and in Canada leprosy does not survive under modern conditions and is slowly but definitely disappearing.

The most hopeful thing about leprosy at present is our changed attitude in regard to the treatment of lepers. It has now been demonstrated that, in institutions where the disease can be treated by approved medical and surgical measures, the course of the infection can be arrested in many individuals and the lot of the others be made immensely happier. From rest in bed, outdoor life, abundant food, a regimen not unlike that practical in tuberculosis, some cases improve steadily and the infection becomes quiescent. Modern surgery can accomplish much. "Disfiguring nodules may be excised, necrosed bones removed, necrotic extremities amputated, and by tracheotomy permanent relief afforded for the laryngeal stenosis so common among the unfortunates" (McCoy). Probably the most important contribution to modern therapy is the use of the drug known as chaulmoogra oil or its derivatives. In many instances this drug can accomplish in a short time what general measures may effect only in months and years. It has been employed on a large scale in the Philippine Islands and especially in Manila, where the board of health has for some years treated leprosy with various derivatives of the crude oil. Recently the Leonard Wood Association has extended the use of chaulmoogra oil with gratifying results and has aroused our hopes for the future. While leprosy will not disappear from the world for long periods, if at all, the disease has passed into the category of ailments which can be helped by modern methods of medicine and surgery, and to a considerable extent be prevented from spreading.

[7] Hopkins and Denny, "Leprosy in the United States." Reprint No. 1274, from the Public Health Reports of the United States Public Health Service, Vol. 44, No. 13, March 29, 1929.

THE HAZARD OF THE AUTOMOBILE

By Dr. JAMES A. TOBEY

NEW YORK, N. Y.

In spite of rigid traffic regulations, constant educational campaigns to promote highway safety, and many other efforts, the mortality from automobile accidents is increasing at an alarming rate in the United States. Automobile accidents now result in about five times as many deaths in this country as does typhoid fever, once a widely prevalent scourge. Such accidental deaths have now reached the unenviable position held by this malady in 1910. Due to the efforts of sanitary science, typhoid fever is a vanishing disease, especially in our cities, and its death-rate in 1929 was about as low as was that from automobiles some twenty years ago. There are now, in fact, only about ten diseases which cause more deaths than do automobile accidents.

Measles, whooping cough, scarlet fever and diphtheria combined do not take any greater toll to-day than does the automobile. There are as many fatalities from automobiles as there are from homicides and suicides together, and there are more deaths from this cause than from either diabetes or appendicitis, and about as many as from diseases of the arteries. Heart disease is now the leading cause of death in this country, but even this affliction has only about seven times as many victims as the automobile. For every four deaths from cancer, there is one due to the automobile. As an instrument of slaughter, the mechanical carriage ranks unduly high.

The situation is undeniably serious and, unlike the mortality from most other preventable causes, is getting worse. Twenty years ago the automobile, then somewhat more rare as a possible agent of destruction, was a negligible factor in the mortality tables, but to-day it is responsible for more than 2 per cent. of the total of almost a million and a half deaths which occur annually in the United States. If the present rate of increase continues, as it has for the past decade or more, automobile accidents will eventually be at or near the head of the list. The facts call for immediate attention and urgent action, in addition to the many attempts now being made to cope with the situation.

Nearly a million persons suffered more or less disabling injuries in automobile accidents in 1929 and a definite increase has been recorded for 1930. In 1929 there were more than 31,500 deaths, a rate 13 per cent. higher than in the previous year, although the number of cars registered increased only 8 per cent. There are now about 27 million motor vehicles to infest the highways, and any tourist will tell you that most of them seem to be in action every Sunday. It is estimated that there are 700,000 cars in New York City alone, and another 900,000 in the metropolitan area. In 1910 there were less than 30,000 in this same city. Not only is the death rate from automobile accidents rising in the general population, but it is increasing per 100,000 cars. From 1918 to 1926 the number of accidents per car declined, but since that time it has been steadily augmented each year.

Since 1910 the mortality from automobile accidents has gone up almost 1,000 per cent. The rate for the country as a whole in 1928 was 20.8 deaths per 100,000 population, though in many states it was much greater. California had the worst record, with a rate of 38.5, according to the figures of the United States Bureau of the Census. Delaware was second, with 30.7 and

Florida third, with a rate of 28.6, which was, however, slightly lower than in 1927. The states with the two largest cities, New York and Illinois, had rates above the United States as a whole, but not excessive in comparison with some other commonwealths, though much higher than was proper or creditable. The New York rate was 22.1 per 100,000, while that in Illinois was 23.6.

In all the states except eight there were increases in automobile accidents in 1928 over 1927, and there were still further increases in 1929. The lowest rate in 1928, according to the latest available data, was in Arkansas, but its figure of 10.9 showed a considerable increase over the 8.8 of the preceding year. In the Hawaiian Islands the rate went up from 16.7 to 26.0 in that one year.

This growing menace from the motor vehicle has not been checked in 1930, as the data from the Bureau of Census for 78 large cities showed 655 deaths from automobile accidents during the four weeks ended January 25 of this year, whereas there were 612 deaths in the corresponding period of the year before. The rate has increased just 11 per cent. in the first month of the current year. For the 52 weeks ended March 22, 1930, the rate was even higher. It represented, in fact, an increase of 147 per cent. over the mortality for 1920. Later records are similarly appalling.

Motor fatalities are no more prevalent in urban areas than in rural. In New York State an investigation of these accidents in 1927 revealed that the death rate outside of New York City was higher than in that metropolis, being 26.6 per 100,000 for upstate, 18.3 for New York City, and 22.3 for the state as a whole. After allocating the deaths to the locality where the accidents occurred and not where the deaths took place, it was discovered that the rate for rural New York was 39.3, as against 19.4 for urban New York, or some 51 per cent. higher among the drivers in the open country.

These unreasonably numerous automobile deaths affect every age and class of our population. Children under fifteen years of age are the unfortunate victims in from 35 to 40 per cent. of all these casualties. Dr. Ray Lyman Wilbur, Secretary of the Interior, was right when he stated recently that a rattlesnake is a domestic pet compared with the automobile. "Rattlesnakes," says Dr. Wilbur, "kill about a thousand persons a year in the United States, but approximately a hundred thousand children will be killed or maimed by automobiles within the next twelve months. We take the automobile for granted because it is useful, but this usefulness comes to us at great cost."

What is the reason for all this carnage by the modern automobile? The answer lies, of course, in the human element concerned. The careless, the arrogant, the unfit, the unbalanced and the drunken driver are at fault in most instances. Congestion of traffic, better roadways offering opportunities for speeding, lax licensing requirements, and possibly greater mental and emotional instability, due to the complexities of modern life, are all factors. It has been estimated that at least 10 per cent. of all automobile drivers are unfit to handle such a complicated mechanism as a moving motor vehicle. Probably the estimate is conservative.

Statistics from eleven states having nearly one third of the total automobile registration of the country, which were collected recently by the Travelers Insurance Company, revealed that the licenses or registrations of 77,704 motorists were suspended or revoked out of a total of 7,178,111 registrants. Driving while under the influence of liquor, excessive speed and failure to report an accident were the principal reasons for these revocations, though in three states all or most of them were the result of an

attempt to mix intoxicants with driving ability, or inability.

Many persons are physically or mentally incapable of being skilful drivers of automobiles, even if they do operate cars. Others may have been competent when their licenses were first issued, but have since become incompetent because of age or some acquired physical handicap. A considerable proportion of the automobile accidents are, in fact, caused by experienced drivers, or at least by persons who have had licenses for a number of years. Few, if any, states have re-examinations, and none requires a complete physical and psychiatric examination of an applicant. At the annual meeting of the American Medical Association in Detroit last June, a report was adopted urging that all drivers of motor vehicles ought to have physical examinations by reputable physicians, so that vision and other important items could be checked up.

European requirements regarding the fitness of automotive drivers are more stringent than in the United States. In sixteen European countries, Germany, Bulgaria, Denmark, Danzig, Esthonia, France, Great Britain, Holland, Hungary, Latvia, Luxembourg, Norway, Poland, Sweden, Switzerland and Jugoslavia, a medical examination of all prospective drivers is compulsory, according to the results of an investigation made in 1928 by a Belgian scientist, Professor Weekers, for the *Association Professionelle Internationale des Medecines*. In France and Great Britain, such examinations must be made only of drivers of public vehicles, but in other countries they apply to all drivers, and in some instances they must be repeated at regular intervals, sometimes one, two or five years. How meticulously the requirements are enforced does not appear from the study.

A clinical study of 100 traffic offenders brought before the Recorder's Court in Detroit resulted in the startling revelation that one of the violators was psychotic, or insane, 12 were definitely feebleminded, and 42 had inferior intelligence. Of the whole lot, only 13 were given a clean bill of health as safe and reliable drivers, though 97 of the 100 had officially issued licenses. Nearly one half of the subjects before this clinic for drivers were seriously handicapped by alcoholism. Such operators as these not only have accidents themselves, but cause trouble to others.

That there is some glimmer of hope in the present American situation with respect to the holocaust of automobile fatalities is indicated by a recent investigation made by the Metropolitan Life Insurance Company of New York. Although deaths from this cause were increased in the aggregate in 1929, there were 24 cities which actually displayed a decrease. An inquiry was sent to the appropriate official in each of these outstanding cities, and 15 were courteous enough to reply. The most conspicuous activity in every one of these municipalities was a campaign of safety education in the schools, although due attention was also given to effective traffic control.

Education in the principles of safety for drivers and pedestrians, plus strict enforcement of reasonable licensing requirements and inspection of automobile equipment, seems to offer a solution to this problem. More courteous road conduct, the curbing of reckless driving, especially when the motor vehicle operator has been plied with poor liquor, and attention to the mechanical condition of the car will do much to reduce the many unnecessary and preventable accidents which are now accounting for too many postponable deaths and avoidable injuries. Complete medical examinations for all drivers and rigorous exclusion of the unfit is undeniably a step that will have to be taken sooner or later.

WHAT THE FOOD AND DRUG ADMINISTRATION DOES

By T. SWANN HARDING

MT. RAINIER, MARYLAND

THE food and drug law, passed in 1906, had two major purposes. It was designed first to safeguard the purity of food and drug products and, secondly, to enable consumers to avoid economic fraud. It was intended then to protect the health and the pocketbooks of the public and this purpose was to be accomplished by keeping package labels, and the advertising matter distributed with food and drug packages, absolutely truthful. Enforcement was first vested in the Bureau of Chemistry. This bureau was composed of both research and regulatory units and, by July 1, 1927, it was discovered that greater efficiency would result if these were separated. The Bureau of Chemistry and Soils was then organized as an administrative unit designed to undertake research work and the Food, Drug and Insecticide Administration (the word "Insecticide" was dropped on July 1, 1930) came into being to enforce the food and drug law and five other similar acts relating to tea, caustic poisons, import milk, insecticides and fungicides, and naval stores, such as turpentine, etc. Precisely the same officials had charge of the enforcement of this law as before; they could merely work more efficiently. Furthermore, exactly the same regulations were followed by them in law enforcement as had served the old Bureau of Chemistry. This much should be said to avoid all initial misunderstandings.

The law is not perfectly enforced. No law is. This particular law costs us but a penny per caput in the matter of enforcement and only 530 employees, but half of whom are technicians, are hired for the enforcement of all six laws administered by the Food and Drug Administration. Furthermore it is rather ridiculous anyway that the law should have jurisdiction over package labels and over the statements made in printed matter accompanying packages, whereas it is without authority to control statements made by manufacturers regarding the very same products in newspaper and magazine advertising, over the radio or on billboards. That leaves a large loophole for faulty enforcement and requires officials to concentrate on read-the-label propaganda when what is really needed is to have all advertising statements honest wherever they appear. Finally, we can see that it is obviously impossible for so small a force spending so little money to run down every violation of the law. When we further consider that 22 labored steps are required from the time goods are seized until a case is closed, and when we remember the crowded condition of the courts, we can see plenty of reason for the exercise of considerable ingenuity to arrive at efficient enforcement of the law under the circumstances. It is also plain that the law needs strengthening, whereas to-day powerful economic forces seem determined to emasculate and further weaken it if possible.

Nevertheless the food and drug law is better enforced to-day than ever. This may be charged to a variety of factors. In the old days under the Bureau of Chemistry every case stood by itself. Inspectors were accountable to a central authority rather than to the chiefs of branch laboratories which were then, as now, conveniently located. Seizures were made irrationally and hit or miss.

Even if a case was finally won it stood entirely alone and unrelated to the work on other cases by the same bureau. Today, all that is changed. The eighteen branch laboratories of the administration have been organized into an Eastern, a Central and a Western district with headquarters in New York, Chicago and San Francisco. Chiefs of branch laboratories are really chiefs, and both inspectors and chemists are accountable to them. Campaigns of procedure are carefully planned in advance and followed rigorously, although they are always sufficiently elastic to permit a special assault when conditions necessitate, as in the most recent influenza epidemic when a variety of fraudulently labeled remedies suddenly sprung up and demanded action. The establishments of manufacturers are themselves examined and reports made to district headquarters. In case of questionable factory processing, shipments of the goods produced are followed into other states and inspectors on duty there make seizures rationally and with some reason to expect fraud. No case stands alone, but takes its place in an orderly plan. Educational and corrective means are used wherever possible, both because it has been found that they will give the public greater protection, if less noise and excitement, than jail sentences, and also because it appears that 95 per cent. of our manufacturers are quite ready to cooperate with the government in complying with the law once they understand what is desired.

To give a complete picture of this law enforcement work in the brief space allotted is impossible. We must therefore narrow the subject and use certain specific types of remedies and the campaigns against them as illustrations to show how the administration proceeds with its work and what protection it offers the American public against quackeries and falsely advertised remedies. We shall not consider foods but limit ourselves to the drug products which in recent years have fraudulently purported to do the impossible. Thus in June, 1929, a report was made on a special campaign waged against rheumatism "cures" during which action was taken against 245 such products. In fact rheumatism cures have, for some reason, led the list of fake remedies against which the Food and Drug Administration has recently had to take action. The evils of self-diagnosis are quite apparent here, for more aches and pains are carelessly regarded as "rheumatism" by laymen whereas they may be symptoms of fundamental disorders —local infections, tuberculosis, venereal disease—which need prompt specific treatment. Again, while laymen commonly regard gout and arthritis deformans as rheumatism, they are not that at all. In fact the trouble may be nothing more formidable than fallen arches. Certainly no one form of treatment could possibly remedy all these varied aches and pains and even more certainly products composed of simple plant extractives, red pepper, turpentine and impotent mineral salts—common ingredients of rheumatism "cures" —could be expected to accomplish little therapeutically.

Mention of rheumatism brings to mind the fact that many of the remedies for this disease, which so far completely baffles medical science, played upon popular knowledge of and respect for what are supposed to be radioactive substances. Hundreds of such preparations were examined by the administration in a recent campaign and less than 5 per cent. of them contained any radioactive substance at all; these usually contained such material in quantities entirely too small to have any physiological effect—so small in many cases indeed that the patient would have to drink several gallons of the concoction daily to produce an effect. These products came in various forms; some were to be steeped in water, others to be hung over the bed

in small bulbs. An active product of this kind would be an exceedingly dangerous thing for a layman to use and it is perhaps fortunate, in a way, that so many of them were frauds of an impotent character. This particular type of trickery has been pretty well cleaned out for the present, but it must always be remembered that new frauds can come into existence with almost incredible rapidity.

In this connection one of the difficulties the administration faces might be emphasized. In the case of court action the case has to be so clearly presented that a jury of laymen will somehow comprehend the technical points involved and act in accordance with the scientific evidence presented. But suppose a remedy, like Gowan's Pneumonia *Cure* of early days, is suppressed, as this one was by Notice of Judgment No. 180. It can become, as this one did, Gowan's Pneumonia *Remedy* and is then ready to face a further fight. Ultimately it became merely Gowan's Pneumonia *Prescription*. It later appeared in 1928 as Gowan's *Preparation* and was then an application recommended for pneumonia, pleurisy, croup, colds, coughs, throat troubles, soreness, rheumatism, congestion and inflammation. It was an external ointment composed of phenol, menthol, camphor, turpentine and quinine sulfate, certainly incapable of acting remedially against many of the pathological conditions named on the label. These claims were restricted, but in 1929 a new manufacturer had bought the famous preparation and, while the label recommended it only for colds, burns, bruises, sprains, sunburn and insect bites, it was advertised in the press as useful to avoid influenza, coughs, croup, bronchitis, etc., conditions which the label no longer listed. This illustrates two things: first, that a product can change its form and its claims quickly and frequently, and thus require continual watching while acquiring temporary immunity; secondly, that after its package label is scientifically correct, it can make impossible claims in newspaper and magazine advertising which, being outside the scope of the Food and Drug Act, can not be prohibited.

During the influenza epidemic new remedies flooded the market and well-known preparations began to make unwarranted curative claims. Zonite, for instance, advertised itself in the press as "striking directly at influenza" if it were evaporated in a flat dish on a radiator; it recommended itself likewise for dandruff, wounds, ulcerations, pimples, boils, eruptions, sinus trouble, sore throat, etc. It is a solution of sodium hypochlorite yielding approximately 1 per cent. of available chlorine. Notice of Judgment No. 16217 issued September, 1929, declared its more comprehensive claims false and fraudulent. Nozol, which consisted of a heavy petroleum oil containing menthol, camphor and a red dye, claimed to be "unequaled in cases of Catarrh, Hay Fever, Asthma and General Nose Troubles" and to relieve sinus trouble; in the press it offered sure protection against flu. Notice of Judgment No. 16221 issued September, 1929, declared its label claims false and fraudulent. In a press release issued earlier this year the administration said:

> Reports on some 800 preparations sold as cures or preventatives of influenza, grippe, or pneumonia have been sent in to the Food, Drug, and Insecticide Administration from the field since the first of the year, when an intensive campaign against falsely labeled products of this type was launched. These reports, giving the results of factory inspections and examinations made by the field stations, in conjunction with the labeling accompanying the packages in interstate commerce, have served as the basis for the procedure adopted by the administration for driving from the channels of trade so-called remedies for which promises that can not be fulfilled are made.
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> The consensus of present-day reliable medical opinion is that no competent drug treatment exists for influenza, grippe, or pneumo-

nia. Nevertheless, as shown by this campaign, many makers of proprietary remedies came forward during the recent "flu" epidemic with products represented as certain cures, but which were totally unreliable, thus hoodwinking the public, a large fraction of which is gullible when its health is concerned, into a false feeling of security and forcing unfair competition upon vendors of truthfully labeled articles. . . .

The labels of many preparations are in perfect compliance with the law, making no therapeutic claim that might not reasonably be expected to be met by a combination of the ingredients used, but the advertisements for these same preparations spread flamboyantly over whole pages of magazines, trade journals, and newspapers, and broadcast by radio, show much less restraint. Many of these advertisements do not hesitate to state unqualifiedly that the products in question can prevent or cure influenza, grippe, pneumonia and certain other diseases. This kind of misrepresentation can not be reached under the Federal food and drugs act as it now stands.

The administration has also taken action against numerous antiseptics recently. It is a curious fact that many manufacturers had never had their products tested in order to see whether they actually were capable of destroying bacteria; many of them believed that a substance, like carbolic acid, would be antiseptic in no matter what dilution it was used. In many other cases it was a question of time of contact: if the reputed antiseptic could be permitted to remain in contact with the infected surface sufficiently long antiseptic action might take place. But the time required for some mouth washes, for instance, would be fifteen minutes, whereas such preparations are usually rinsed about in the mouth and almost immediately expectorated. On the other hand, if a product were made sufficiently powerful in its antiseptic agent to act antiseptically in the time claimed it would be exceedingly likely to take the tissues of the mouth along with it when expelled. A general cleanup of the antiseptics followed and their labels were rendered truthful.

One widely advertised preparation might be mentioned which advertised in the press that there were 80 square inches of tissue in the mouth where the germs causing 30 diseases originate. Bacterial decay was said to start here in a food film which existed throughout and most other antiseptics would merely mask the odors accompanying this process. But this new antiseptic cleaned the mouth, killed the bacteria, and removed all decay and all odor thereof. What were the facts? Of the 30 diseases listed —and bronchitis, croup, diphtheria, leprosy, typhoid fever, parotitis, influenza and scarlet fever were among them—only *one* can be traced to the mouth area which contains more nearly 50 than 80 square inches. The mouth parts do not extend from the lips to the first rib as pictured in the advertising. There is no wide-spread food film therein at any time to decay at 90° F. The alkaline saliva counteracts the poisonous quality of the small amounts of decaying food which can collect, and, kept in the mouth the brief period recommended, the antiseptic would do little or nothing. In short the product was just another mouth wash of pleasing taste and of little or no therapeutic or germ-destroying value.

A final word might well be said about antifat "cures." In proceeding against these the Food and Drug Administration labors under the slight limitation that obesity can not clearly be shown to be a disease. Unless a drug product makes false claims to remedy disease it is a little hard to proceed against it and antifat remedies, like superfluous hair removers, tend to stand with cosmetics rather than drugs. The superstition is old that soap and water are bad for the face; it arose when soaps really contained considerable free alkali and often did injure many delicate faces. To-day it stands cosmetic manufacturers in good stead and they continually add to

their lines all sorts of auxiliary preparations, including antifat remedies.

For this reason the following words by Dr. F. F. Cullen, of the Food and Drug Administration, are not without interest:

> Promoters of so-called obesity remedies and fat reducing cures are attempting to influence fat people to spend money for worthless or dangerous preparations. The advertisements appeal to the vanity of persons who wish to regain slim, graceful figures and also to the business necessities of those who become so fat that they can no longer do their work efficiently. The principal appeal of most of the promotion claims is that no dieting is necessary; the medicine is to do it all and the advertiser says the patient can eat all he wants and as often as he wishes, which is a strong inducement to most stout people.
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> These preparations frequently contain thyroid and laxatives. The promiscuous use of thyroid may prove very harmful unless given under the advice of a physician personally familiar with the subject's physical condition. The department has on record an instance where death has followed an overdose of a preparation containing thyroid. Some preparations contain poke root (phytolacca), a poisonous drug, and others, analysis shows, contain nothing that could possibly have the slightest effect in reducing flesh.
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> The promoters of one preparation assert that it secures most marvelous results by a process of elimination of foods without digestion. These people guarantee the reduction of a pound a day. A preparation of this character, if it did what its makers claim for it, would probably eliminate any need of digestion in the future. Another product, examination shows, consists principally of ordinary soap. The idea is to apply this locally with friction and thus remove the fat wherever it may be in excess. A still more clever scheme provides chemicals to be added to the water in which the patient is to bathe. These chemicals are of such a nature that they form a sort of curd in the water after the patient has bathed. This curd, the advertisement states, is fat and surplus tissue removed from the body. Other schemes offer tablets at 75 cents a dozen which are claimed to reduce fat at the rate of a pound a day.
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> No other class of preparation exploited to humbug the people has a wider sale than these so-called fat reducers, and nearly all the preparations are absolutely worthless. Often patients seem to lose weight, but this is to be attributed to the hot baths and the diet and exercises recommended to accompany the medication.

The latest work published tends to show that the metabolism of fat people is the same as that of the lean; they use their food chemically in the same manner. Careful dieting and proper exercise are the only safe methods of weight reduction, and these must be used with extreme care especially by persons who have long carried about excess flesh. In many cases ancillary physical conditions make it unwise for fat people to try to reduce weight rapidly and as a general rule their reduction in weight should be carried out under the supervision of a competent physician who has made a special study of obesity.

By exercise of its powers over interstate and import commerce the Food and Drug Administration has removed from the market many preparations falsely labeled for cure of disease and reduction of fat. Seizures and court actions have resulted in destruction of the goods and, in some cases, fines for the manufacturers. Most manufacturers have now revised their labels to comply with the food and drug act. Some of the less scrupulous manufacturers continue to make false claims in advertisements, circular letters, pamphlets and the like, not accompanying the package, over which the administration has no legal control. For their protection the Food and Drug Administration advises purchasers to compare the printed claims on the labels of such medicines with other claims made by the manufacturers. If there is a discrepancy it is wise to depend on the label rather than on printed matter that does not accompany the package.

SELLING ENTOMOLOGY

By AUSTIN H. CLARK

U. S. NATIONAL MUSEUM

ENTOMOLOGY is not usually regarded in the light of a commodity subject to sale and purchase. Yet entomologists consider that their calling is of value as well as of personal interest to them, and some one else must consider it of value or they would not be able to continue their careers as entomologists.

It is my present purpose to explain just how entomology happens to be a commodity, to emphasize the necessity for securing an increased sales value, and to indicate how this desirable end may be accomplished.

Just as we can not understand the broader relationships of a tree by contemplating only its outer twigs and flowers, so also we can not understand the true position of entomology in our social scheme until we know how the seed was sown, how the little plant became rooted in our social fabric and what made it grow.

I have spoken of entomology as a tree, but it is really one of the branches of an enormous tree—the tree of science. Many times in the course of human history this tree has attained a considerable growth, has died back, then grown out again in a different direction, and again died back. It is now flourishing as never before; all its branches are healthy and luxuriant, and are constantly giving off new twigs and branches.

If the tree of science is to maintain a healthy growth its roots must reach far down into the fundamentals of human society, far enough down to receive a constant supply of nourishment from the basic sources of power in that society. So before we study the tree itself we must first examine the soil and the nutritive material afforded by it.

The fundamentals of human society are very simple. They consist of the production of foods and their distribution, coupled with the necessary defense of the individuals and social units engaged in this production and distribution. No matter how complicated a human social system may become, all lines of activity may be interpreted as functions of one or the other of these two fundamentals.

Power in any human society is ultimately based upon the ability to control, in one way or another, the production or distribution, or both, of food. Power is therefore chiefly centered in two classes in the population. The first class includes those who through the possession of wealth in one form or another are able to control far more food than they require for their own use. The second class includes those who are able to influence others in such a way as to exert a corresponding control. In any community, therefore, the real power is vested in the wealthy classes and in the politicians.

From this it naturally follows that science, as well as every other line of human activity which is not of obvious immediate concern in the raising of food, must, in order to prosper, secure the patronage of one or both these classes.

Bearing these facts in mind, let us briefly trace the history of entomology in this country. It was about the time of the Revolutionary War that insects, along with other forms of animal life, first began to attract the attention of native observers and naturalists. After the Revolution, with the progressive westward expansion of agriculture on an increasingly large scale, with the in-

tensification of agricultural operations in the Eastern states, with the cultivation of new crops, and with the appearance of new pests, native and introduced, insect depredations gradually attracted more and more attention.

As the area under cultivation became larger many agricultural journals appeared, while many journals, magazines and daily papers not primarily agricultural devoted a considerable amount of space to agriculture.

Up to the time of the Civil War by far the largest part of the published information concerning insects, especially injurious insects, was to be found in the daily, weekly and monthly papers and periodicals, especially those of the South and Middle West. As samples of journals which more or less frequently printed articles dealing with entomology I may mention the *Prairie Farmer, American Farmer, Maine Farmer, New England Farmer, Illinois Farmer, Genesee Farmer, Lancaster Farmer, Farmers' Cabinet, Southern Planter, Western Rural, Rural New Yorker, Cultivator and Country Gentleman, American Gardening, Gardeners' Monthly, Massachusetts Magazine, Iowa Homestead, De Bow's Industrial Resources,* and *Harper's Magazine.* But besides these there were many others.

Although a few were very good, most of the articles appearing in these journals were not very serious contributions to entomological literature. They were written by all sorts of people in many different walks of life; but there were at that time none who could properly be called professional entomologists.

Of the two dozen authors who up to the time of the Civil War made contributions of real worth in the field of entomology in the United States the most outstanding and conspicuous was Thaddeus William Harris, the librarian of Harvard College. Under appointment as commissioner of the state of Massachusetts he published in 1841 a treatise entitled "A Report on the Insects of Massachusetts which are Injurious to Vegetation." Subsequent editions of this report appeared in 1842, 1852 and 1862. For the preparation of this work Mr. Harris received the sum of $175, which was the first money ever paid in this country for work in entomology.

A dozen years after the publication of Mr. Harris' report—that is, in 1853—Dr. Asa Fitch was appointed official entomologist by the state of New York, the first state entomologist to be appointed, and in the same year Townend Glover, an Englishman born in Rio de Janeiro, was appointed as an "expert for collecting statistics and other information on seeds, fruits and insects" under the Bureau of Agriculture in the United States Patent Office in Washington.

Now let us look into the status of entomology as a serious study and occupation in this country in the days before the Civil War. In the time of Thaddeus William Harris—and indeed quite up to the outbreak of the war—science in general and entomology in particular was regarded as wholly unworthy of the attention of any mature person. Any one devoting his attention to science was more or less shunned; he was regarded as only one degree removed from the village imbecile—a pathetic case of arrested mental development.

Mr. Harris once wrote to his friend, Mr. Doubleday, in England congratulating him upon the fact that he was not "compelled to pursue science as it were by stealth, and to feel all the time, while so employed, that you are exposing yourself, if discovered, to the ridicule, perhaps, at least to the contempt, of those who cannot perceive in such pursuits any practical and useful results."

In England at that time science was much more highly regarded than it was in this country. Immediate practical results were not demanded there. It is

easy to say that the reason was because in England science had a social prestige which was lacking here. If the Earl of Seaforth chose to collect butterflies, or Lord Valencia saw fit to send home from distant countries pickled starfishes, humbler folk who occupied themselves more or less in the same way could not be ridiculed without showing a certain amount of disrespect for these noble lords. And in those days the lords were far too powerful to be treated with disrespect by any one but other lords.

So far as it goes this explanation is correct, but it does not go far enough. The difference in the status of science in this country and in the England of that time was simply a reflection of the difference in the allocation of power.

In England, if any one succeeded in gaining control over a very large amount of food production or distribution through the acquisition of land or any other form of wealth, he was created a peer of suitable rank, or a baronet, and according to the English system his wealth—that is his power—was passed down through succeeding generations. In the same way the successful politician who gained control over a large number of people engaged in the production or distribution of food, or the successful general who defended the food sources and markets of England against aggressive and destructive competition or who enlarged or extended them was created a peer, and if he was poor means were found of giving him wealth so that his power should be perpetuated in his family.

Thus the English system was based upon the conservation and concentration of power. Once power was accumulated it theoretically passed on unimpaired from generation to generation. Those who inherited the power were relieved of the necessity for creating power on their own account. They could, if they wished, occupy themselves wholly with unpractical affairs. This many of them naturally did, some taking up various lines of science and many others supporting science with their surplus means.

Our system was very different, especially after the Revolutionary War. Our inheritance laws were such that it was impossible to perpetuate power in successive generations indefinitely, and public sentiment was strongly opposed to all efforts toward that end.

The natural result of this was to exaggerate the importance of the personal accumulation of wealth, and hence to regard all forms of human activity in the light of their bearing on the accumulation or the display of wealth.

In both England and this country wealth and power were synonymous, as they always are everywhere. The difference between England and this country was that in England many individuals were in a position in which they were relieved of the necessity of constantly striving for power; with their inherited power, often advertised and augmented by the possession of a title which went with it, they were so secure in their position in the social system under which they lived that almost anything they might do would be considered praiseworthy. In this country, on the other hand, almost every one endowed with energy and ambition was obsessed with the desire for increasing to the maximum his personal power and prestige, and the intensity of the struggle on the part of each individual was greatly increased by the uncertainty regarding the fate of his wealth after his demise.

The natural result of the difference in the social attitude toward wealth and power in England and in this country was a corresponding difference in the type of science which found the greatest popular favor in the two countries.

English science maintained an aristocratic aloofness from the common run of human activities corresponding to the detached social status of its patrons.

The only accepted science in England was pure science, uncontaminated by any suggestion of evident economic application. To the average English scientific man the idea that his work might be of economic significance was as unwelcome as the suggestion that a lord might turn shopkeeper. The results of English research were embalmed in scholarly treatises printed in most dignified scientific journals, or in books of unassailable respectability. Naturally we had brought with us from England the same tradition, and we had already established a few excellent scientific journals, but these were all confined to the northeastern section of the country and were scarcely a factor in the growth of entomology.

Our work in entomology, largely very crude, was mainly to be found described in the pages of weekly or monthly magazines and in the daily papers, and by far the greater part of it had a direct bearing on the economic aspect. It was of no interest to any one not directly concerned with crops, and as its value in terms of dollars was not at the time evident it made no particular appeal to anybody.

While quite naturally all our scientific men of Mr. Harris' time who had been brought up more or less according to the English tradition deplored the attitude toward science in this country and envied their English colleagues, I believe it was a good thing. It put science on its mettle. Entomology especially had to fight for recognition. Recognition won by an uphill fight is always on a solid basis. And to maintain their position among recognized, accepted and respected social activities all branches of science must rest on a firm and solid basis. If science relies entirely or chiefly on the social prestige of a limited group of aristocrats it will rise or fall with those aristocrats.

In brief, up to the time of the Civil War scientific work in this country was rather sharply divided into two lines which had little in common. One line was carried on in the cloistered atmosphere and under the protection of colleges and academies where so far as possible the transplanted aristocratic English tradition was followed. The other line was a new and independent growth springing directly from the more intelligent elements in the general mass of the population. Entomology with us was chiefly of the latter type, the more philosophical phases of the study of American insects, and those aspects which required extensive reference collections and libraries being carried on almost entirely in Europe.

During the Civil War the withdrawal of the young men from civil life necessitated by the formation of armies brought about a great scarcity of labor. This had an immediate effect. Industry was hampered in all directions, which led to the rapid development of all sorts of mechanical contrivances, and the improvement of others, to enable one man to do the work of several.

In that period also the problem of food for the civil population as well as for the armies became more or less acute. This had the effect of drawing general attention to the enemies of food plants, particularly insects.

Furthermore, the social emotions resulting from the excitement of the times had the effect of breaking down to a large extent the barriers between the social classes.

So at the time of the Civil War industry combined with physics to increase its power—or rather the slowly growing rapprochement between industry and physics received an enormous impetus. The insect problem had no appeal for the industrialists, but it had an immediate appeal for another group wielding great power—the politicians in the rural districts and in the farming states.

The application of science to industry, and especially the development of

economic entomology, was very greatly aided by the social conditions of the time which tended to break down the barriers between the cloistered academic workers and the isolated and more or less untrained, though often capable and brilliant, "amateurs."

The period following the Civil War has been called a period of great intellectual awakening in this country. But people do not awaken intellectually. Through visions of financial gain or hopes of enhanced personal prestige they get their eyes opened to the advantages of adopting for practical reasons something which, in the absence of any true understanding, they had previously been apologetically calling intellectual. Reduced to its lowest terms, this simply means that knowledge which up to this time had been the exclusive intellectual property of a single class, or of a few classes, after the Civil War became of interest to, and the common property of, all classes capable of appreciating and of using it.

So what really happened after the Civil War was that industry discovered something of value in the physical sciences, while the leaders among the farmers began to find that there was something to be gained for them from an appreciative cultivation of the natural sciences. The vision of dollars looming ever more clearly in the background placed all branches of science in this country on an increasingly firm basis of social respectability.

The industries and the physical sciences are now so closely bound together that the physical, engineering and chemical departments of our universities are mainly trade schools preparing men to take their place in industrial life. By far the largest part of the research work done in physics and in chemistry to-day is carried on in the laboratories of industrial corporations or at least in close association with them.

The attainment of social respectability by science as a whole reached its culmination in the establishment by Mr. Andrew Carnegie and by Mr. John D. Rockefeller of great organizations devoted to pure science. Enormous as has been the scientific advance which has resulted from the public-spirited generosity of these gentlemen, their real contribution was that they permitted their names to be linked with pure science. In the minds of the common people, thinking in terms of purely American standards, they put the stamp of their approval, and therefore the seal of respectability, on pure science. They did just what Lord Seaforth, as viewed by English standards, had done for entomology one hundred years before.

That science is now firmly established in the appreciation of the American public was graphically illustrated by an important event that took place only a few weeks ago. At the first showing of his new picture Mr. Charles Chaplin had with him as his guests of honor Professor Albert Einstein and Professor Robert A. Millikan. What does this mean? Fundamentally, of course, it means that Mr. Chaplin saw in Professors Einstein and Millikan possibilities for more free newspaper space devoted to his new picture than could be secured by the presence of any other guests. Conversely, it means that science, as represented by relativity and cosmic rays, holds the public interest at least to the same extent as a new picture by Charles Chaplin. In the light of the differences between our social system and that of England this event was, so far as the recognition of science is concerned, quite the equivalent of the bestowal of a peerage on Sir William Thomson (Lord Kelvin) in 1892 and on Sir John Lubbock (Lord Avebury) in 1900 by Queen Victoria.

Now let us return to entomology. During the Civil War C. V. Riley, a young Englishman, published some

articles on economic entomology in the *Prairie Farmer*, with which he later became connected as reporter, artist and editor of the entomological department, this work being interrupted by a short period of service in the 134th Illinois Volunteer Regiment. In 1868 he was appointed state entomologist of Missouri, and while in this position published a series of nine annual reports which may justly be called the American classics in economic entomology.

At the close of the Civil War flights of that destructive grasshopper known as the Rocky Mountain locust had caused considerable damage, and in 1874–76 this insect became a really serious menace to agriculture in the regions west of the Mississippi. The very extensive depredations of the locusts received more or less notice in all the papers in the country.

As a result of Mr. Riley's efforts, Congress on March 3, 1876, established a commission, under the direction of the United States Geological Survey, to investigate the Rocky Mountain locust. The commission was composed of Mr. Riley as chairman, Dr. A. S. Packard, Jr., secretary, and Dr. Cyrus Thomas, treasurer. The establishment of this commission was an important event in being the first real recognition of the desirability of supporting organized scientific work in economic entomology under Federal auspices.

Having now become a well-known national figure, Mr. Riley was appointed entomologist in the Department of Agriculture in June, 1878. In this position he served continuously until June, 1894, except for a period of two years when he was replaced by Professor John H. Comstock.

From the time of the Civil War the study of entomology has rapidly advanced. The number of entomological organizations and of entomologists has steadily increased, and various entomological journals have been founded. It is not too much to say that this advance in entomology has been mainly the result of Mr. Riley's work.

I have traced Mr. Riley's career at some length in order to emphasize the very important fact that his success rested on the appreciative regard for him on the part of the plain people. Through the popular contacts made while he was on the staff of the *Prairie Farmer* and his understanding of the average man, he was able to develop to the maximum the position of state entomologist of Missouri. With the development of numerous additional contacts made while holding this position he was able to bring about the establishment of the Rocky Mountain locust commission, and his work as chairman of that commission made him the logical choice for entomologist in the Federal service at Washington. Of course, had it not been for his extraordinary natural ability he could not have succeeded as he did. At the same time had he not had the opportunity for making broad popular contacts, and the capacity for developing those contacts, his natural ability would have availed him little.

At the present time entomology is in danger of losing those intimate popular contacts which were so firmly established by Mr. Riley and greatly broadened and extended by his successor, Dr. L. O. Howard. Entomological, like academic, salaries are largely fixed, continuing unchanged, or at least undiminished, from year to year. This in itself gives rise to a feeling of security and a sense of detachment from the world at large which tends to obscure a true appreciation of social responsibility.

But we must always remember that in entomology, especially in economic entomology, the power which serves to support and to further research work is lodged in the hands of the representatives of the people. For insects are more of a menace to those directly con-

cerned with the growing of farm products than they are to any one else. So we find that by far the greater part of entomological work to-day is being carried on by means of money raised by general taxation, federal or state, and is more or less immediately under the control of politicians who derive their support more or less directly from the population of farming areas.

Now politics is the science of the possible as applied to human affairs. The average politician must act strictly in terms of the wishes of his constituents. If you wish to do business with him you must talk the language of his constituents, for that is the only language he understands. You must always remember that he will pay more attention to a laborer in his district than he will to you, because that laborer with his vote may affect his future career. Naturally it wounds our pride to have this brought home to us, yet no politician would be worthy of the trust imposed in him if he did not think more of his constituents than he does of us.

As a professor of the great science of the possible the average politician can only afford to see what is more or less clearly visible to his constituents. Therefore the more enlightened his constituents are on any subject, entomology included, the more enlightened he will be.

Most people depend for their knowledge of things in general, and of what is going on in the world about them, on the daily press. This may be supplemented by various magazines and books, but broadly speaking the daily press is by far the most potent factor in general education. Some newspaper or other is read by, or to, every constituent of every politician. You will find that for the most part the average man's idea of entomology is a composite of the ideas conveyed to him through his favorite newspapers and magazines.

Since the support of entomology in this country is vested chiefly in the hands of politicians, big and little; since in the nature of things politicians are primarily spokesmen for their constituents; and since these constituents are educated entomologically, as in other ways, chiefly by the daily press, it naturally follows that the status of entomology as a science with us will be dependent upon its exposition and interpretation in the daily press.

From what has been said it is evident that the study of entomology first began to attract the serious attention and support of the American people when it was presented to them by Mr. Riley and others in the light of something of real and tangible value—that is, in the light of a commodity worth buying. It is further obvious that further expansion of entomological work is dependent upon the hope and expectation of increased benefits to be gained—that is, upon an increased sales value.

It remains to be shown how the public appreciation of the facts of entomology, and of the benefits resulting from the study of insects, may be increased.

The responsibility for this rests directly upon the shoulders of the entomologists themselves. It is their duty to see that the readers of the public press, who provide the support for the greater part of the work now being carried on in entomology, are themselves provided with abundant and accurate information on the subject.

Entomology has now become so very technical, and entomological work is so time-consuming and exacting, that it is no longer possible for working entomologists to supply the press directly with the required information. Yet at the present time the press desires and can use far more information than can be supplied. Perhaps the greatest stumbling block in the way of supplying the press with the desired material is that the language of the press and the language of entomology are very

widely different. Yet it is the plain language of the press that must be used in reaching ordinary people. To the average reader larva means molten rock, nymph means a kind of outdoor chorus girl, and pupa means nothing. Can we overcome this difficulty?

This difficulty was foreseen and has been overcome by the press itself, on its own initiative. Entomologists have at their service a corps of able interpreters writing the language of the press but with a thorough appreciation of, and respect for, science.

In 1921 Mr. E. W. Scripps established an organization known as Science Service, the function of which is to provide the press with news or information on scientific subjects accurately written in popular language. Science Service is at present under the direction of Dr. Vernon Kellogg, well known as one of our most eminent entomologists.

Since that time science has rapidly gained in popular favor, and one by one the great press services, groups of papers and large independent dailies have designated special men of proved ability as "science editors," whose business it is to see that scientific news and information is properly presented in the papers under their control.

There are now about fifteen of these science editors, all but two of whom are college men. They come from Harvard, Amherst, Cambridge (England), Western Reserve, Columbia, Cornell, George Washington, New York University, the University of Illinois, the University of Michigan, the University of Chicago, the University of London, and some other universities. Two at least are doctors of philosophy, and two themselves give courses in universities. Of the two who are not college men, one received the Pulitzer prize for his accurate and brilliant work in reporting the Boston meeting of the American Association for the Advancement of Science in 1922.

These men are among the outstanding writers of the country. They write in the language of the press, yet at the same time appreciate and are able to understand the language of science. They are the interpreters of science, and at the same time its salesmen. Between them they provide most of the scientific items that appear in more than three thousand papers. The output of one of them alone goes to nearly thirteen hundred papers. The press is doing everything it can to present science to the people in the proper light.

There is another difficulty. What sort of science do the people want? As I said before, ours is a business country. We take the business attitude toward everything. With us science is a business, or perhaps more truly a department of a larger business. In order to prosper it must be advertised and sold, just like any other business, and in much the same way as any other business.

Each country has its own peculiar attitude toward science. I may illustrate this by a little story. One evening a number of friends were gathered together—an Englishman, a Frenchman, a German, a Pole, a Russian and an American. After a long and perhaps too convivial discussion they agreed that each should prepare a treatise on the elephant. The Englishman spent a year in Africa and after his return produced an entertaining little volume entitled "Elephant Hunting in East Africa." The Frenchman spent six months in Africa and six months in India and published a little book called "The Elephant and his Love Affairs." The German spent five years in the field, visiting all the regions wherein elephants are to be found, and then five years working in the libraries of Berlin, after which he produced a huge two-volume quarto entitled "An Introduction to the Definition of an Elephant."

The Pole thought it unnecessary to leave Warsaw. After a year or so he produced his book, which was called "The Elephant and Its Bearing on the Polish Question." The Russian also found it unnecessary to leave home. After due deliberation he produced a delightful iconoclastic book entitled "The Elephant—does it Exist?" The American joined a Cook's tour around Africa and India and on his return wrote an inspired treatise called "Bigger and Better Elephants."

Now there is no denying the fact that the American people like to read about bigger and better science. The calm cold expositions of scientific fact one reads in the English and in the German press could never be printed here. Popular presentation must be to a certain extent along bigger and better lines. Yet even in this respect a compromise can easily be reached which will not be too distasteful to the most solemn of scientific men. Some years ago physics and chemistry overcame all squeamishness in this matter, and entomology can do the same. Is calling *Melanolestes* a "kissing-bug" any less dignified or detrimental than referring to cosmic waves as a "humpty-dumpty phenomenon"?

Any form of human activity is appreciated in proportion to the amount of space devoted to it in the newspapers, just as the importance of any firm or corporation is judged by the relative size of its advertisements. Thus in this country murder is regarded as one of the most interesting and entertaining of human occupations. So for newspaper space science must compete with murders—bigger and better murders.

You may not realize it, but newspapers do not like to put emphasis on murders. Even the most sensational among them prefer to print other kinds of news. But in order to live papers must print what the people wish to read. In order to replace murders the papers must have something to print which is equally entertaining, or can be made equally entertaining, for the average person. As there is a fixed amount of space available in a newspaper, any increase in the amount of scientific news and information published is at the expense of other types of more or less similar material. The interest of the scientific information therefore must be equal to that of the material replaced.

Now writing for popular consumption is a specialty which has as a prerequisite natural aptitude based on exceptional mental equipment. This natural aptitude must be developed by a long process of intensive training under conditions involving constant and most bitter competition. A successful writer is in capacity and in training quite the equal of the successful delineator of the embryology, life history or ecology of an insect. While he may be stricken completely dumb by the description of a new species of chalcid fly, he can describe protons, electrons, the red shift, etc., in such a way as to flatter you into thinking you know what he is talking about. And after a short interview you will find that he can describe a chalcid in such a way as to make a physicist believe he understands the creature, and furthermore wish to know more about it.

It is chiefly because of the extraordinary ability of these writers on science that the relative amount of science printed in the papers is rapidly increasing at the expense of other types of material, and correlatively that public appreciation of science is rapidly increasing.

Now in this increase in the amount of science appearing in the public press entomology has not participated to anything like the extent that was to have been anticipated in view of the fact that of all branches of science in this country the study of insects is perhaps most

closely dependent on the good-will and support of the people; that entomology in America may almost be said to have arisen from the people, as evidenced by the great amount of material which in the early days was published in popular journals; and that the greatest figure in American entomology laid the foundation for his work by writing for a popular journal. It is high time that entomologists took steps to correct this situation.

I shall close with a word of warning. As things stand at present we are facing a distinct and growing menace. We are developing a mechanistic and dehumanized culture which is rapidly becoming unintelligible and therefore irksome to the great bulk of our population. Signs of a reaction are already at hand. We are beginning to show symptoms of philosophical indigestion. Mechanization is proceeding faster than the development of our ability to incorporate it into our ideas of things as they ought to be. Materialistic as we are, we are outrunning our philosophy. As an illustration, biographies lately have become extremely popular. We do not care whose biography we read, but we like to be taken back to the days in which the subject lived. Life as it was in those days appeals to us. Conversely, dehumanized dial telephones do not, in spite of their superior efficiency.

The chief requisite of science as it is portrayed to-day in the daily press is a return to fundamentals—more extended notices of these lines of science which after all come closest to us. We must have more information on living things, and especially on those living things that immediately affect our welfare. Chief among these are the insects.

SCIENCE SERVICE RADIO TALKS

PRESENTED OVER THE COLUMBIA BROADCASTING SYSTEM

THE INDIANS OF THE DISTRICT OF COLUMBIA

By Dr. WALTER HOUGH

HEAD CURATOR, DEPARTMENT OF ANTHROPOLOGY, U. S. NATIONAL MUSEUM

THERE are many evidences that before the coming of the white man Indians had their villages in what is now the District of Columbia. These Indians spoke the language of the great Algonquian family which covered the east coast, and for this reason the Algonquians were met by John Smith at Jamestown and by the Pilgrims at Plymouth. Much more is known about the Virginia Indians than of the northeastern tribes seen by Winthrop, because Sir Walter Raleigh sent along with John Smith a competent artist who drew pictures of the natives, their houses, dances, occupations, and of animals of the sea and land. Accustomed as we are to the buckskin of the western Indians, we will be surprised to know that Powhatan's braves had nary a shirt to their backs, robes taking their place. The women wore short skirts and the children dispensed with clothes. Of course, in the cold months of winter the Indians withdrew into their houses and enjoyed the stores of corn, smoked fish, hickory nuts and such things as they had laid up. The houses were of bent poles covered with mats and were in shape like a hayrick seen on farms.

Such houses were spaced with some regularity into villages, surrounded by cornfields, and having a dance plaza smoothed by the bare feet of the celebrants around the central fire. Secotan was a scattered village among the trees, while Pomeioc was massed in a circular palisade of sharpened stakes. John White made pictures of these towns and they may be regarded as typical Algonquian architecture and village planning. We may thus restore to the mind's eye a great village on the Eastern Branch and call it the ancient capital of this region.

It may seem unfortunate that the District of Columbia Indians left so few traces of their life here. Archeologists trained to the work are able to see much in small things and to tell the story without straining the imagination. One picks up an arrowhead, say, at Anacostia. It is of a certain stone and worked from a boulder most likely at the Piney Branch quarry. He knows that the arrow was fixed with sinew at the end of a wooden shaft, straight and smooth, which was notched at the end to receive the string; also that it was feathered to guide its flight.

He knows further that there was a bow to project the arrow and that it had a sinew or Indian hemp cord. Then it is evident that there was a man in charge of the bow, arrow, quiver, and so forth. The arrowhead was found at Anacostia, inhabited by the Nacotchtank Indians, and we have got our man, equipped for the hunt or battle. The arrowhead was found at Anacostia and belonged there because it is the right kind of stone. Another variety of stone would indicate that it was a point made by the hostile Indians living on the Susquehanna or where the certain stone was found. Perhaps the archeologist picked up a fragment of pottery and derived a most interesting story from it. Especially it would tell him that the Indians lived in a village of houses because fragile pottery can not stand rough Indian transportation, and was therefore made on the spot from native clay.

So the story widens with the bits of

the old times picked up, everything having an Indian man or woman once living and breathing at the other end. The hunt for the Indians is not made with a spade and the fingers, but with the informed mind. The District of Columbia Indians were in the stone age, and imperishable stone tools left in the soil are silent though eloquent of the old times. So many of the implements are of a stone called quartzite that archeologists earnestly desired to know what was the source. Dr. W. H. Holmes and De Lancey Gill, archeologically sleuthing here and there over the District, found quartzite boulder beds in the once beautiful valley of Piney Branch and saw chips and partially worked cobble stones lying about. Here, said Dr. Holmes, appears to be the quarry. Subsequent ditching revealed that here was one of the greatest Indian quarries discovered in the United States.

Thousands of tons of chips and other quarry refuse lay under the tree-covered gentle slopes of Piney. Dr. Holmes' trenches showed that the boulder bed had been worked in places to the depth of 28 feet. An incredible amount of labor had been expended here to fashion by blows of stone upon stone leaf-shaped blades, the blanks from which arrowheads and knives were made in far-off camps. In the old days of the District of Columbia a temporary camp of mat houses would be seen on the level tract of Blagden's, above the quarry. This village site was discovered by the speaker when the war garden bared the soil undisturbed by the plow for more than a century.

The river life of the Potomac in 1608 must have been very interesting. John Smith tells of divers savages in canoes, well laden with the flesh of bears, deer and other beasts. Some of these dug-out canoes are in the Potomac mud no doubt now. There were many places to paddle not open to-day. Boats could move about freely where the new government buildings are going up, and the Eastern Branch was a great river 300 years ago. At night, reflected in the undulating Potomac, were the lights of the torches of fishermen, and over the smouldering fires of the primitive gridirons the catch was smoked for the winter. Down the river and around the coast went canoes filled with furs, meat and corn for aboriginal trade.

Land trails also centered in the District, leading to the Susquehanna and on to the West. Braddock used an old trail to Cumberland worn deeply in old times by Indians in moccasins. Railroads must follow these old trails in another day, giving little thanks to the native road builders. Sometimes among the débris of lost villages one comes upon a bit of fashioned soapstone, a shard of an ancient vessel. Thin, smooth and well formed, this bit shows the skill of the Indians of the District of Columbia. Not satisfied with determining the size and shape of a soapstone pot from a fragment, Dr. Holmes sought out the places where the Indians quarried soapstone, finding several small quarries in the District where they had worked. The story could not be completed here, but in a quarry in the old District towards Alexandria he found bosses of soapstone worked out on the face of a deposit. The bosses were the round bottoms of future soapstone pots, the next step being to knock these bosses off and excavate them with the rude pick chisels of stone left about by the workers. Thus lightened, the unfinished pots were carried to the camps and finished to the taste of the cooks who had use for them.

In its natural conditions or only slightly aware of the presence of man, the District must have been an ideal place for savage life. Every family could have a deer a day and not decrease the herd; a bear once in a while, wild turkey, water birds, fish, roasting ears and ripe corn would vary the fare. Not too thickly planted by nature for the

Indian, also, but a dare to the early American with his steel axe. Its massive trees were his harvest.

The coming of the white man to Jamestown in 1607 was a small entering wedge into a vast territory, and perhaps we would think it of little effect on the District. On the contrary, in 75 years there was not an Indian left in the valley of the Potomac, the same story that became old as the white man pushed the remainders west. The District was settled by hardy pioneers and a new line of history began.

TELLING THE NATION'S TIME

By Captain FREDERICK HELLWEG

DIRECTOR U. S. NAVAL OBSERVATORY

I WONDER how many of you have ever given any thought to the question of how the nation's time is obtained, how it is kept, how it is transmitted to the millions of people, and how important a part accurate time plays in the life of every one.

How many times a day do you suppose the question is asked by some one: "What time is it?" Ask the Western Union Telegraph Company why they had to stop telling people the time. Thousands and thousands of telephone calls all over the country were pouring in on the telegraph company's offices: "Will you please give me the correct time?" until the interference with their business was so serious that they reluctantly had to refuse to answer the question. The U. S. Naval Observatory had to stop answering the question for the same reason. Our telephone lines were being choked by requests for time so that our legitimate business was interfered with. I have told you this to show you how many times a day some one wants to know the time.

The duty of keeping the nation's time is a very important and a very technical one. Every nation in the world maintains a costly time service, for you know the determination of the time is expensive. Instruments for observing the stars, chronographs for recording the exact instant when the celestial bodies cross the meridian, precision clocks for maintaining the time accurately—all these are very expensive. Then add to this the cost of the labor, including astronomers who observe nightly the stars as they cross the meridian of the observatory, the highly technical computers who calculate the time based on the observations, the electricians who handle the many electrical details of keeping the time, the radio experts who broadcast daily the exact time to the hundredth of a second, the telegraph personnel who signal the time to all parts of the continental limits of our country, all these make the sum for keeping the nation's time mount very rapidly. And yet, it is well worth it. Without accurate time many things could not be developed.

Do you know that mineralogists and geologists depend on the Naval Observatory's exact time to assist them in hunting for the vast oil deposits hidden away in the bowels of the earth? Would you be surprised if I told you that scientists depend on the observatory's time signals in their investigations of gravity? Of course you all know that the navigators on ships at sea listen daily for our time signals in order to navigate their ships safely across the seven seas.

How many of you know that all the important boundary commissions which determine the boundary lines between nations, between states, and between communities are dependent for the es-

tablishment of their lines accurately upon the time signals broadcast from the observatory? To show you how extensive is the use of our time signal, in 1921 the Naval Observatory broadcasted a special time signal upon the request of the Australian Boundary Commission, which was establishing the boundaries between the provinces in Australia. This last summer we were requested, and later thanked, by the director of the Canadian Geodetic Survey, for our assistance in their boundary work between the provinces of Ontario and Manitoba, and also for our assistance in their work in Saskatchewan. Without exact time, the wonderful train service that spreads throughout our land would be a hopeless mess and the loss of life would be very great. There is hardly any activity in our entire country that is not directly affected by the question of time.

Before telling you how we keep the time, it may be of interest to you to know that the initial effort in the United States was made by an amateur astronomer, William Lambert, who presented a memorial to Congress in 1809, recommending the establishment of a first meridian in the United States at Washington. Lambert had determined the longitude of Washington and submitted his calculations with his memorial to Congress.

In 1845 observations of the sun, moon, planets and brighter stars were inaugurated at the observatory and have been continued ever since. In 1849 the first practical chronograph, called a magnetic clock, was built. That was the first time that electricity had been employed in the recording of observations at the observatory. This old clock is now in the museum at the Naval Observatory. Between 1854 and 1860, three minor planets were discovered by the Naval Observatory astronomers, but it was not until 1873 that the observatory was equipped with a large refracting telescope. At that time it was the largest one in this country.

Having given you this brief history of the U. S. Naval Observatory, the place where the time is kept, and the place which tells the time to the nation, I will now briefly describe how we calculate the time and broadcast it to the world.

As the earth rotates, the stars in the heavens appear in the east and after swinging across the heavens set in the west, just as the sun appears to do. The only difference between the sun and the stars is that the stars appear to make the round-trip in almost the true period of the earth's rotation, while in the case of the sun a little more than a revolution is necessary to bring the sun back again to the meridian. I will not explain the reasons for this as any one can obtain them from any book on astronomy in any of the public libraries. As the stars are not within the earth's orbit (in fact they are so far distant that their apparent positions are only very slightly affected by the earth's motion), the period of the earth's rotation, measured in reference to a point in the sky called the vernal equinox, is one sidereal day. This period is the most accurate standard of time measured. The earth's rate of rotation is constant and the stars move very slowly with reference to the vernal equinox, so that they are very reliable as reference points to measure the time of the earth's rotation.

Here at the observatory we use small telescopes, known as transit instruments, for observing the stars. These instruments, as their name indicates, are used to mark the exact instant the star passes across the celestial meridian. The celestial meridian is a line in the heavens which passes through the north and the south points and also through the zenith of the place where you are situated. The sidereal time at which each star will cross the meridian is calculated. For greater accuracy we select the stars

which cross the meridian near the zenith of Washington, and also the stars whose exact positions are most closely known.

The exact time, according to the clock, that the stars cross the meridian is very closely determined, and the difference between the time that the stars should cross the meridian and the times they are found to cross the meridian according to our clock, is the error of the clock. These errors are very accurately determined.

Down in a vault, specially made, and maintained summer and winter at a uniform temperature and at a constant air pressure, are three standard sidereal clocks which keep the most accurate star time possible. These clocks are never reset or interfered with in any way except in the case of necessity for repairs. The actual rate of each clock is determined by checking with the actual time the stars cross the meridian, and then by applying these corrections to the face time of the sidereal clock, we know the exact sidereal time.

The standard time of the United States is called "standard mean solar time." Owing to the irregularity of the earth's motion in its orbit and to the inclination of the earth's axis, apparent solar days vary in length during the year. For obvious reasons it is necessary that all days and all hours be of the same length, therefore a mean solar time has been established and this is sometimes ahead of and sometimes behind the apparent solar time, but on the average it is the same.

In order to reduce confusion, standard time zones have been created. All the points in each zone use one uniform time. These zones are on even hours and are measured from Greenwich which is considered the zero meridian. For instance, in continental United States there are four time zones—the Eastern standard time is the local time of the 75th meridian and this is exactly five hours behind the Greenwich standard time; Central standard time is the local time of the 90th meridian which is six hours behind Greenwich time; Mountain standard time is the local time for the 105th meridian which is seven hours behind the Greenwich time; and, the Pacific standard time is the local time of the 120th meridian which is eight hours behind the Greenwich time; and the servatory is thus able to furnish one time signal which will provide time for all the zones. Our time signals are sent out at noon, at 10 o'clock in the evening and at 3 o'clock in the morning.

The time signals are broadcast automatically by means of special transmitting clocks. These clocks contain electrical mechanism by which they may be set within one hundredth of a second. They also have an electrical break circuit apparatus for emitting the signals. Before each signal these transmitting clocks are compared with the standard sidereal clocks in the vault by means of a chronograph, and are then set electrically within a hundredth of a second of the correct mean solar time. From 2:55 A. M. to 3:00 A. M., from 11:55 A. M. to noon, and from 9:55 P. M. to 10:00 P. M., Eastern standard time, dashes are broadcast, beginning on each second except that there is no dash transmitted on the 29th second of each minute, nor on the identification seconds at the end of the minutes. This is done so that any one listening will know that if one beat is missed the next beat will be the 30th second of a minute. From the 55th minute up to and including the 58th minute there are no ticks for the 56th, 57th, 58th and 59th seconds. This lets you know that the next tick, after omitting four beats, represents the beginning of the minute. On the 59th minute there are no beats sent from the 50th second until the 60th second. This allows any one who is listening for the tick to realize that after the silence of nine seconds, when the next tick is

sounded it is the zero hour—either 3:00 A. M., noon, or 10:00 P. M. The telegraph companies transmit only the noon signal, and in transmitting the noon signal they only transmit the last three minutes. They used to transmit the whole five minutes but for economy's sake they shortened the time to three minutes.

Our time signals have been broadcast by Arlington on high power since December, 1912. Our time service goes much farther back than that, as the first time signal was broadcast by the Navy in the spring of 1904. But it was not until 1912 when the big Arlington station was completed that it was possible to broadcast our time signals with sufficient power to reach around the world. As you all know, radio signals are much better received at night than during the daytime. We therefore inaugurated the 3:00 A. M. time signal for the convenience of observers away out in the Pacific.

The Naval Observatory is a national institution and many visitors to Washington avail themselves of the opportunity to visit it, and view the many very interesting things here. As the observatory is our national observatory, your observatory and mine, it is believed that every visitor to Washington should make it a point before leaving town to spend a few hours very profitably going through this very wonderful institution.

HOW UNITED STATES PAPER MONEY IS MADE

By A. W. HALL

DIRECTOR, BUREAU OF ENGRAVING AND PRINTING

As your announcer has just stated, I am talking to you from a press room in the Bureau of Engraving and Printing, at Washington, D. C. The humming sound you hear in the background is that of machinery producing paper money. Every five seconds one printing press turns out twelve notes. There are 240 presses in daily operation. When these presses are engaged upon the printing of one-dollar bills the output averages $28,000 a day for each press, and when printing twenty-dollar bills the output averages $560,000 a day for each press.

I shall attempt to describe, in nontechnical terms, the various operations employed in the production of paper money. Before going into details I want to give you briefly some general information regarding the Bureau of Engraving and Printing. It was not until July 11, 1862, that the United States government undertook to engrave and print its own securities. In keeping step with the ever-increasing demands made upon it, the bureau has gradually grown until to-day it employs 4,500 persons to whom $10,000,000 are paid yearly in salaries and wages. The building which the bureau occupies is located on the bank of the Potomac River about one mile south of the White House. The main building, which is of Roman Doric architecture and of limestone and modern construction, is 555 feet long, 296 feet deep, and 105 feet high. The main building provides ten acres of floor space, while the auxiliary buildings provide about four acres. In addition to the production of paper money, this bureau prints all the postage stamps, revenue stamps, bonds, certificates of indebtedness, disbursing officers' checks, liquor prescriptions, transportation requests, commissions, warrants, and numerous other classes of engraved and lithograph work for the United States government and its insular possessions. Of the total person-

nel, 55 per cent. are women. During the last fiscal year the face value of securities printed and delivered by the bureau amounted to fifteen billion dollars. In addition to this 12,500,000 sheets of checks, drafts, commissions, certificates, etc., were also printed.

Last week the Honorable Walter Ewing Hope, assistant secretary of the treasury, described the various kinds of paper money in circulation. This afternoon I shall endeavor to describe the many processes employed in preparing these various kinds for circulation. Except for the final operation on national bank currency, the processes employed in producing paper money are identical for all kinds. You will notice that the national bank currency bears the name of the bank of issue, the charter number and the signature of the bank officers, which are not required on United States and Federal Reserve currency.

The first step in arranging for the production of paper money is that of preparing the designs. When a new issue, or a new note, is to be placed into circulation this bureau consults with the officials of the various offices involved, and the conclusions reached as to the character of the design are embodied in a model. After this model receives the approval of the Secretary of the Treasury, the design is reproduced in soft steel by several expert engravers, each one engraving his allotted portion. Since each engraver specializes in different lines of engraving, such as portrait, vignette, ornamental, lettering, etc., the entire design of any one note does not represent the work of any one engraver. Sometimes as high as six different specialists in engraving are employed in the engraving of the completed note.

The work of the various engravers who contributed to the design on the note is then brought together on one piece of soft steel, which, after having all imperfections removed, is hardened. The hardening of this steel is accomplished by heating it in cyanide of potassium and quickly dipping it in cold oil or brine. This piece of steel is known as the die and it is never used for printing, for the reason that the large number of impressions required to be printed would soon wear it out. The hardened die is placed on a transfer press and a soft steel roll is rolled over it under tremendous pressure until the soft steel of the roll is forced into the lines of the engraving of the die, reproducing the design in relief on the circumference of the roll. The roll is then hardened and rolled over a soft steel plate, thereby reproducing an intaglio, or cut-in, impression on the plate. The engraved plate, when hardened by the same process as employed in hardening the die, which is done to increase its durability, is cleaned and made ready for the printer. By repeating these transfer operations an unlimited number of steel printing plates of perfect duplicate engravings can be made from one original engraved die.

Within recent years a new process of plate making was developed in this bureau. This new process is accomplished by electro-deposition, and plates made by this process are called electrolytic plates. Some idea of the principle of the electro-deposition may be gained from the nickel-plating equipment of your local jeweler. First a steel plate is placed in a chemical bath and a layer of copper deposited upon it. When the copper is separated from the steel plate we have what is called an alto plate, bearing the design in relief. This alto is placed in a bath, upon which are built alternate layers of nickel and copper, and which when separated from the copper plate has the design in intaglio or cut-in form. The face of this plate is hardened by the application of two ten-thousandths of an inch of chromium, a metal next to the diamond in hardness. Both steel and

electrolytic plates are used in this bureau for the printing of paper money.

Only the highest grade paper is used for printing paper money. It is manufactured by private contractors under government specifications and supervision. Red and blue silk fibers are distributed throughout the sheets, so as to make this paper distinctive. It is a violation of the statutes for any unauthorized person to possess any of this distinctive paper, except in the form of lawfully issued currency or securities.

All the ink used in printing paper money is manufactured by this bureau through mixing dry colors, bases, oils, etc., in large kneading mixers, which resemble those seen in large bakeries for mixing dough. Barytes is the base for most plate inks. The dry colors are made from coal-tar dyes, ground minerals and chemical precipitations, more of the latter two being used on account of their resistance to light and atmospheric influence.

The blank sheets of distinctive currency paper are received in lots of one thousand sheets, and every blank sheet brought into this bureau is charged against the bureau on the books of account maintained by another office of the Treasury Department. Each sheet passes through a specially designed device called a wetting machine. In this machine the sheets pass under a spray of water which makes them soft and pliable and receptive to the ink. Four days after the sheets pass through the wetting they are ready for the first printing operation. The back of the note is printed first. Each printer operating a press calls for the number of sheets he can print in one day. He obtains this paper from the division in which the paper is prepared for printing. The printer is charged with these sheets. The press upon which the printing is done is called a four-plate power press. The printing plates are strapped to attachments called planks and the four planks each carry a plate which travels in circular fashion. At one point the entire face of the plate is covered with ink, at the next point the surplusage of ink is wiped off by a mechanical oscillating wiper. Then the printer polishes the plate with his bare hands, taking care to leave the cut-in lines of the plate filled with ink. A blank sheet of the moistened paper is laid on the plate, and immediately following this the plate with the paper on it passes under a pressure roller. The pressure exerted by this roller forces the paper into the lines of the plate and the paper takes up the ink. The sheet is then picked off the plate. The four plates continue in this fashion without interruption during the time the press is in operation. As each impression is made a mechanical counting device registers it. Every two hundred printed sheets are removed from the press and hand counted. At the close of the day the requisition signed by the printer for the number of sheets withdrawn for printing is checked against the amount reflected on the mechanical counting register and the number of sheets counted by the representatives who remove them from the press. A reconciliation of these three amounts must be accomplished before the printer or his assistants are permitted to leave the building.

All sheets printed during the day are sent to a large room, which is heated by steam, where they remain overnight. During the night the moisture is driven out of the sheets and the surface of the ink dried sufficiently to permit handling. The slip sheets inserted at the time the currency was printed are then removed and each sheet given a careful examination by experts. Sheets bearing the slightest defect are rejected. The perfect sheets are returned to a vault where they are permitted to dry out for a period of three or four weeks before starting through the next print-

ing operation. The second printing operation, or that of printing the faces, is likewise preceded by wetting. The operation of printing the faces is identical with that of printing the backs. The perfect sheets continue through subsequent operations. The imperfect are delivered to another agency of the department, which certifies to their destruction, giving this bureau credit on the books of account for the amounts so destroyed.

Next the sheets are resized. In this process the sheets pass through a solution of glue, the thin coating of which makes the paper more durable. The sheets are then pressed by a process known as calendering. In this process the sheets of currency are interleaved with a heavy cardboard, and packs of sheets arranged in this manner are sent through a set of large rollers. These rollers exert tremendous pressure, which irons out all the wrinkles and restores the gloss. Next the sheets are trimmed to the required size by a machine which takes the margin off the four sides at one time. The serial numbers and United States seal are next printed on the face of each note. In this operation the sheets are automatically fed into a very unique machine which not only prints the numbers and seals on each note, but simultaneously slits the sheets in half. Each half is delivered to another section of the machine and drawn through a set of slitting knives which reduces each half to six separate notes. The notes are dropped into a collator, which mechanically gathers them up in numerical sequence and delivers them to an examiner in packages of one hundred. After careful examination the notes are banded in lots of one hundred each. Forty of these packages of one hundred notes are strapped together by steel bands, which are electrically welded. An outer covering of brown paper bearing the label showing the contents completes the package for shipment to the various issuing agencies.

The annual output is approximately one billion notes, the production of which consumes 1,125 tons of paper and 1,100 tons of ink. In passing through the many operations a sheet of currency is hand counted fifteen times and mechanically counted three times.

Within recent years the public has become so much interested in the work of the bureau that it has been found advisable to publish a pamphlet explaining the various processes and operations employed in printing not only currency but the many other classes of work produced by this bureau. This pamphlet is on sale at the office of the Superintendent of Public Documents, Washington, D. C., at 10c a copy. When you visit Washington you should make it a point to see the bureau in operation. It is open to visitors during certain hours of the day.

PHILOSOPHICAL IMPLICATIONS OF MODERN PHYSICAL SCIENCE

By Professor J. RUD NIELSEN
DEPARTMENT OF PHYSICS, UNIVERSITY OF OKLAHOMA

THE influence of science upon modern life is largely indirect, taking place by way of technology. Through the ever-multiplying horde of machines profound changes are being wrought in the environment of human beings, and men are given a greater and greater potential control over their own destinies. What use will they make of these newly acquired powers? What revision of human ideals and social instrumentalities is demanded by the new situation? These are very pertinent questions which form perhaps the most important challenge to philosophy at the present time.

In addition to this indirect influence upon philosophy, especially upon the theories of human values, science has a direct bearing upon the general theory of knowledge. After all, any theory of knowledge worthy of attention must be derived from a study of the procedure by which knowledge is actually obtained, *i.e.*, from an examination of scientific method. It is natural, therefore, that the enormous extensions of our knowledge of the physical world in the last generation, which have necessitated the first really deep-going revision of the fundamental physical concepts and axioms since the days of Newton, should present important problems and correctives to epistemology. To point out some of these is the purpose of this article.

Before starting, let us settle a question which may have entered the minds of some of my readers. With what right does a physicist undertake to discuss philosophical problems? Ought he not to confine himself to physics and leave philosophical questions to the philosophers? Well, that is what physicists have generally done. But frankly, I consider it well within the right of a scientist to discuss any problem which has grown out of his science, even if the problem is of a very fundamental and general nature. And such problems are forced upon physicists, for, as Helmholtz once said, no matter what physical problem one starts with, if one pursues it far enough it will become a philosophical problem.

Moreover, in attacking a philosophical problem the physicist does not necessarily step outside the boundaries of his science. His problem does not cease to be a physical problem when it has become so general that it is properly termed philosophical. There is no sharp dividing line between physics and philosophy. As the Austrian epistemologist Schlick says, "Philosophy is not an independent science—rather is it hidden in every science as the true soul of science." The greatest among scientists have been inspired by motives which may rightly be called philosophical. As W. F. G. Swann writes in a recent issue of *Science*, in commenting upon Einstein's publications, "It has been our philosophic desire rather than the needs of experiment which has driven us to hope for a correlation of gravitation and electromagnetism in one general scheme." The work of Bohr on atomic structure has been inspired by the dream of being able to derive all properties of a chemical element from a pure number, the number giving the place of the element in the periodic system of Mendeleeff.

Mechanics is the oldest physical science. In fact, by the end of the eighteenth century it was developed by

Newton and his followers to nearly the degree of perfection that it possesses to-day. In the nineteenth century the importance of mechanics was immensely enhanced when it was found that many phenomena which do not offhand appear as belonging to mechanics could nevertheless be described quite adequately in mechanical terms. Thus we got a mechanical theory of heat, and the phenomena of electricity, magnetism and light were explained on the basis of the idea of an elastic ether pervading all space.

The phenomena of chemistry were described in terms of Dalton's theory of atoms. The atoms were miniature billiard balls with inertia as their most important attribute. In addition to having mass, they were hard, elastic, impenetrable, indivisible and indestructible. They were assumed to attract or repel each other with so-called central forces. A physical phenomenon was considered as completely explained only when it was described in terms of atoms moving under the influence of central forces.

The great fruitfulness of the mechanistic tendency in physics naturally led to a strong faith in Newton's laws of motion as the ultimate principles governing the physical world. The world was conceived as a machine, as a clockwork ruled by strict causality and therefore completely predetermined. This view was adopted and elaborated by the philosophers of the materialistic school, and it influenced no less the ideas of philosophers in other camps. When the old conceptual framework began to break under the pressure of the development known as modern physics, a number of philosophers of various complexions came to the aid of conservative physicists in defense of the Newtonian scheme.

The growth of physics in the period from about 1895 to the present time is without counterpart in the history of science. The enormous extension of our experimental knowledge and at the same time the complete reconstruction of the conceptual framework from the bottom up which have taken place in the last three or four decades were possible only through the working together of a number of factors. Without attempting a thorough analysis, I shall mention the factors which I believe were of greatest importance. First, the progress in the design and construction of scientific instruments and in the art of experimentation; second, the genius and daring of such theoretical physicists as Planck, Einstein and Bohr; third, the great development of mathematics in the nineteenth century, and fourth, the increasing number of scientific workers and the growing international cooperation in scientific work.

The subject of modern physics may conveniently be discussed, at least in regard to its philosophical implications, under two heads: the theory of relativity and the quantum theory of atomic and molecular structure. The theory of relativity, which was devised to circumvent certain difficulties presented by experiments involving very high velocities, applies primarily to large-scale or cosmological problems, though it is also of fundamental importance on the atomic scale. The quantum theory, which represents our knowledge of atomic phenomena and of radiation, naturally reaches into nearly every branch of physical science; it has, for instance, furnished an extremely valuable clue to the study of the internal constitution of stars.

Since very much has already been written on the theory of relativity and its bearing upon philosophy while very little has yet been written on the philosophical implications of the quantum theory, I shall divide the limited space at my disposal rather unequally between the two theories. I shall treat the theory

of relativity as briefly as possible in order to be able to discuss a little more thoroughly the problems presented by the quantum theory.

In the eighties of last century Michelson and Morley had performed an ingenious experiment the purpose of which was to determine the absolute orbital motion of the earth, *i.e.*, its motion relative to the ether. The experiment gave a negative result: no matter where the earth happened to be in its orbit, there was no indication of any motion of it relative to the ether. This fact, which was corroborated by other experiments, presented exceedingly great difficulties to the theoretical physicists. It was to eliminate these difficulties that, in 1905, Einstein, then only twenty-six years old, proposed his special theory of relativity. If absolute motion can not be measured, Einstein reasoned, then the concept of absolute motion has no meaning and should be abandoned. And guided by the experimental facts, he proceeded to revise completely our concepts of space and time. The supreme importance of the theory which he created lies in the fact that space and time are our most fundamental physical concepts.

To understand the change brought about by Einstein in the concepts of space and time, let us briefly review the positions of Newton and Kant in regard to these concepts. Though Newton professed that "whatever is not derived from phenomena . . . has no place in experimental philosophy," he took over more or less uncritically the contemporary notions of space and time: "Absolute, true and mathematical time flows in virtue of its own nature uniformly and without reference to any external object." Space and time are, so to speak, empty vessels existing independently of their content and of one another. Though Kant recognized the subjective nature of space and time, he regarded them as *a priori* forms of our perception, *i.e.*, as conceptions not derived from experience or subject to revision, but given once and for all. The fundamental spatial concepts such as point, straight line, etc., as well as the axioms of Euclidean geometry he also considered as given *a priori*. In this way he accounted for the absolute certainty which he believed was an attribute of geometry and Newtonian mechanics.

The Kantian view of space and time as *a priori* forms, which really amounted to an acceptance of Newton's absolute space and time, was criticized by Poincaré and others, but the credit for definitely putting space and time in the class with all other physical concepts belongs to Einstein.

In order to define such terms as simultaneity, length, etc., Einstein asked himself: How does the physicist actually determine if two events are simultaneous or not, and how does he actually measure the length of an object? By proceeding in this way, Einstein contributed much to the recognition of the operational character of scientific concepts which has been so clearly emphasized in Bridgman's recent book, "The Logic of Modern Physics."

In the theory of relativity, space and time are fused together into a four-dimensional space-time manifold. The three-dimensional section of this manifold which a certain observer calls space and the one-dimensional section which he calls time are in general different from the space and time of another observer. Space and time are subjective. However, the difference in the spaces and times of two observers depends entirely on their relative motion and not upon their conflicting views on prohibition or the World Court. This relativity of space and time has many striking consequences. Two events which are simultaneous for one observer will in general not be simultaneous for another. If you move relative to another observer, he will

see you flattened up in the direction of your motion and, by closer inspection, will find a subnormal pulse to be another of your symptoms. You, in turn, will see him flattened up and find his pulse to be slow. Unfortunately, it would take enormous relative velocities to observe these curious effects directly. But then, if these effects could be readily observed, they would not be curious, and Newton would have invented the theory of relativity.

Other consequences of the theory, such as the variation of mass with velocity, the existence of an upper limit to velocity, the fusion of the concepts of mass and energy, the modification of the laws of motion, and so on, are of interest chiefly to physicists. I mention them only to indicate how extensive was the revision of the classical conceptions demanded by the theory of relativity.

The theory which has been so far referred to is the so-called special or restricted theory of relativity. It is not necessary to state exactly to what restricted class of motions this theory applies, for in 1915 Einstein succeeded in working out a perfectly general theory which asserts that all motions are relative, *i.e.*, that no matter what the motion of an observer is, his physical experiences may be described by the same fundamental laws. The creation of the general theory of relativity is one of the greatest achievements of the human mind. In commenting upon this theory, the late Dutch mathematical physicist, H. A. Lorentz, said sometime during the war that a hundred years from now this time will be referred to as the time of the creation of the general theory of relativity rather than as the time of the World War. In building up this theory Einstein had to incorporate in it the phenomenon of gravitation. The theory is therefore also a theory of gravitation. He further had to make use of non-Euclidean geometry, the gravitational effects entering in the metric of this geometry. This fusion of gravitational forces with the geometrical properties of space is naturally very desirable, and it gave for the first time an understanding of the well-known fact that weight and mass are proportional. Einstein's most recent work, reported not long ago even in the newspapers, is a successful attempt to incorporate also electromagnetic forces into the general theory.

The departure from Euclidean geometry made possible the solution of a cosmological problem which long had troubled astronomers. According to Newton's theory, the part of the universe which was filled with matter would have to be like an island floating in infinite, empty space. Such a universe would gradually diffuse into the surrounding emptiness. Now, after a slight modification of his theory, Einstein was able to deduce from it a much more satisfactory cosmology, according to which space is more or less spherical in structure, *i.e.*, though unbounded, space has a finite extension, while matter is more or less uniformly distributed over the entire space.

The use of four-dimensional and, still worse, non-Euclidean geometry in the theory of relativity has given rise to much discussion and much misunderstanding. Is space actually non-Euclidean? Or is the use of non-Euclidean geometry simply a mathematical trick which happens to simplify the description of physical phenomena? The former of these two questions is meaningless. Space is neither Euclidean nor non-Euclidean. If we want to call it anything, the most appropriate predicate would be amorphous, as once remarked by Poincaré. What kind of geometry we get depends upon our choice of metric, and we are at liberty to choose whatever metric we please. The second question, if the use of non-Euclidean geometry is

a mathematical trick, must be answered in the affirmative: non-Euclidean geometry is nothing but a conceptual spider-web which is used by physicists for the sole purpose of simplifying the description. This, however, does not separate Einstein's theory from any other physical theory. All theories are spiderwebs of symbols. The truth of a theory consists in its unique correlation with experience, *i.e.*, a theory is called true if there is a unique correspondence between its statements and the field of facts it is designed to describe. Since all experience is approximative, we can never check this correlation with perfect accuracy. Hence, whenever progress is made in the art of experimentation, we must be prepared to discover imperfections in our theories. There is no such thing as final truth.

The explosion of the Kantian doctrine of synthetic *a priori* judgments broke down the barrier which was supposed to exist between mathematics and physics. The ingenious invention of the so-called implicit definitions by which Hilbert succeeded in making mathematics logically independent of physics does not, of course, change the fact that generically mathematics is rooted in experience. If that were not so, the marvelous usefulness of mathematics would indeed be hard to understand.

Let me close the discussion of the philosophical implications of the theory of relativity with a quotation from Schlick's "Space and Time in Contemporary Physics." He says:

> The importance of these results, in their bearing upon the underlying principles of natural philosophy, is so stupendous that even those who have only a modest interest in physics or the theory of knowledge can not afford to pass them by. One has to delve deep into the history of science to discover theoretical achievements worthy to rank with them. The discovery of Copernicus might suggest itself to the mind; and if Einstein's results do not exert as great an influence on the world-view of people in general as the Copernican revolution, their importance as affecting the purely theoretical picture of the world is correspondingly greater, inasmuch as the deepest foundations of our knowledge concerning physical nature have to be remodeled much more radically than after the discovery of Copernicus.

The theory of relativity is mainly concerned with the framework of space-time; the quantum theory, on the other hand, deals with that which occupies space-time. Being a theory of the structure of atoms and molecules and of radiation, it is as all-embracing as the theory of relativity. While the theory of relativity has stimulated only a rather small number of physical experiments or astronomical observations, the quantum theory has profoundly influenced the work in every physical and chemical institute the world over. As a consequence, though the quantum theory of atomic structure is closely associated with the name of the Danish physicist Niels Bohr, it is less than the theory of relativity the creation of a single man.

In spite of its great usefulness in chemistry, the concept of atoms remained fairly hypothetical throughout the nineteenth century. In fact, towards the end of the century, the great successes obtained by the application of thermodynamics to chemical problems led Ostwald and other chemists to abandon the idea of atoms entirely. However, only a few years later, direct experimental evidence for the existence of atoms was forthcoming. This evidence came only after the discovery of the electron and of radioactivity, so before the existence of atoms was finally established it was known that atoms were not indivisible entities, but that they were made up in part of electrons. Since atoms are electrically neutral while electrons are negatively charged, atoms must also contain positive electric charges. In 1911 Sir Ernest Rutherford made the

extremely important discovery that the entire positive charge, and practically the entire mass, of an atom is concentrated in a space exceedingly much smaller than the size of the atom. The picture which he gave us of an atom resembles greatly our solar system. All the units of positive electricity, protons we now call them, and some of the electrons, are concentrated in the so-called nucleus of the atom. Around the nucleus, the remaining electrons revolve at distances from the nucleus which are very large compared with the diameter of the nucleus. An atom, hence, is largely empty space.

At about the same time, Moseley, a brilliant student of Rutherford's, established the fact through his work on x-ray spectra that the number of net positive charges on the nucleus, and therefore the number of electrons outside the nucleus, is simply equal to the atomic number, *i.e.*, the number listing the element's place in the periodic system of Mendeleeff. It was a fortunate happening that brought Bohr to Manchester shortly after the making of these important discoveries. In 1913 he published his first papers on the constitution of atoms and molecules, thereby laying the foundation to the theory which is dominating physics at the present time. The first nine or ten years of the Bohr theory were years of marvelous triumphs, but gradually it became clear that a deep-going revision was required. The decisive step toward such a revision was taken in 1926 by the young German physicist Heisenberg. Following the lead of de Broglie, Schrödinger, also in 1926, created his wave mechanics, which accomplished essentially the same results as Heisenberg's matrix mechanics. These two theories, while quite different in appearance, were soon found to be mathematically equivalent, and both of them are now parts of a more general quantum mechanics which forms a rational generalization of the original Bohr theory. The years from 1926 to 1928 were, indeed, busy years for the theoretical physicists. The complete overhauling of a theory in a couple of years would have been entirely impossible but for the previous work of mathematicians on matrix algebra and on the theory of differential equations. While rapid progress is still being made in perfecting the new quantum theory, there are strong indications that the main features of the theory have reached a stable form.

Parallel to this theoretical progress and greatly stimulated by it and, in turn, greatly stimulating it, exceedingly important experimental advances have taken place. Two of the most important discoveries of the last decade were made in this country. In 1923 A. H. Compton, now of the University of Chicago, discovered that x-rays suffer a small increase in wave-length when scattered by materials of low density. The wave theory of radiation was unable to account for this phenomenon, but it was readily explained on the basis of the corpuscular theory of light proposed a number of years earlier by Einstein. Thus Compton's discovery made more acute the dilemma concerning the structure of light which had greatly troubled physicists for some time. While the phenomena of diffraction and interference show conclusively that light is a wave motion, other phenomena show equally clearly that light consists of particles! The other discovery, made in 1927, by Davisson and Germer, of the Bell Telephone Laboratories, creates a similar problem concerning the structure of the electron. Up to this time all known electronic phenomena were satisfactorily described by picturing the electrons as small particles. However, Davisson and Germer found that a stream of electrons scattered by a nickel crystal exhibited unmistakable evidence of diffraction and interference. This has been verified by other experiments. In fact, we have now just as compelling reasons for

adopting a wave theory of electrons and protons as those which led to the adoption of the wave theory of light a hundred years ago. But how can light and matter be both particles and waves? We shall return to this question later.

In his attempt to work out a theory for the motion of the extra-nuclear electrons and for the emission of radiation by atoms, Bohr naturally sought guidance from the sciences of mechanics and electrodynamics, which adequately describe the motions of large bodies and the ordinary electromagnetic phenomena. However, it was immediately clear that the ordinary laws of motion, and of electrodynamics, do not hold even approximately for the electrons within an atom. Bohr, therefore, turned to the very radical ideas of discontinuous energy changes invoked by Planck to account for the energy distribution in the so-called black body radiation. These ideas, together with a fundamental law of spectroscopy discovered by Ritz, were shown by Bohr to form a suitable basis for a description of atomic processes. In the original Bohr theory the break with mechanics was not complete. The theory was, therefore, more or less of a patchwork of admittedly provisional character until, guided by Bohr's so-called correspondence principle, Heisenberg achieved its complete emancipation from mechanics, thus making the quantum theory as logically self-contained as ordinary mechanics.

The most basic principle in the quantum theory and that which most sharply distinguishes it from the classical theories and gives it its name is the quantum postulate. According to this principle, an atom does not emit or absorb radiation or exchange energy with other atoms or electrons except during a complete transition from one so-called stationary state to another. The atomic processes are therefore essentially discontinuous in character. Many attempts have been made, first by Planck and most recently by Schrödinger, to alleviate this discontinuity or individuality of atomic processes, but these attempts have all failed.

With the quantum postulate, it has been said, an element of irrationality has been introduced in our description of nature. I believe that it would be more correct to say quite the opposite. For certainly the intelligibility of the world depends largely upon the quantum laws. Knowledge, as we know, depends upon recognition. But recognition depends upon the existence of similarities in the objects of perception. Now if the laws of classical mechanics and electrodynamics held on the atomic scale, we should not have a relatively small number of chemical elements with constant and clear-cut properties such as definite valences and spectra consisting of sharply defined wave-lengths. In fact, if it were not for the quantum laws the physical world would hardly have any structure, and physical knowledge would be impossible. Or better expressed, the quantum theory, as an acknowledgment of a definite structure in atomic phenomena, may be looked upon as a guarantee of the intelligibility of the physical world.

The most important consequences of the quantum postulate are embodied in the principle of uncertainty enunciated by Heisenberg in 1927. The substance of this principle is as simple as its philosophical implications are profound. The principle of uncertainty states that to any mechanical quantity Q corresponds another quantity P in such a way that the product of the uncertainties in our knowledge of Q and P can never be less than the so-called quantum of action or Planck's constant. In other words, the more accurately we have determined the value of Q, the greater must be our ignorance concerning the value of P. For instance, if Q is a vector which determines the position of a particle, P will be its momentum, *i.e.*, the product of the mass and velocity of the particle. Hence the more accurately we have

measured the position of a particle, the less can we know about its velocity. In particular, if the position were given with perfect accuracy, we could have no knowledge whatever about the velocity. Or, conversely, if the velocity of the particle were accurately known, we should be perfectly ignorant about its position. Similarly, even if all practical difficulties interfering with the accuracy of our observations were completely eliminated, we could not know with perfect accuracy the energy of a mechanical system at a given instant. The more accurately the time is fixed, the more uncertain must be our knowledge of the energy. If the time is perfectly accurately fixed, we must be totally ignorant of the value of the energy, and *vice versa*.

The validity of this principle follows from a consideration, in the light of the quantum postulate, of the process of observation. In order that we may observe an event a signal of some sort must reach one of our sense-organs. Let us consider a visual observation, in which case the signal consists of a stream of light quanta or photons. Then, in order that we may observe a certain particle, at least one photon must hit the particle and be deflected by it so as to enter our eye or our microscope or photographic camera. But in being deflected from the particle to be observed, the photon imparts a certain amount of momentum to the particle. Now a simple consideration based upon the theory of the resolving power of optical instruments shows that the more accurately we observe the position of the particle, the less accurately will we know what change in the velocity of the particle has been produced by the rebounding photon. In other words, to the extent that we obtain accurate information of the position of the particle, we lose whatever knowledge we may have had of its velocity. Thus the uncertainty principle follows from these two facts: First, that in any observation we have a coupling or interaction between the object observed and the instrument of observation; and second, that this interaction is governed by the quantum laws and, therefore, can not be reduced below a certain value, which, in the example considered, depends upon the wavelength of the light used.

If the particle which we observe has a very large mass, if it is, for instance, one of the planets, then the impact of the light upon it will produce only an exceedingly small change in its velocity. On the other hand, if the particle should be an electron moving around an atomic nucleus in a certain stationary state of an atom, then an observation of the instantaneous position of the electron would bring the atom entirely out of its stationary state, thus making it impossible to observe more than one point of the electronic orbit.

Our knowledge of the physical world is thus restricted not only by imperfections in our instruments and methods of measurement, which we may hope to remove to a greater and greater degree, but also by unsurmountable barriers set up by the quantum structure of the universe, *i.e.*, by the very structure which makes the world intelligible.

Now if all physical knowledge is thus limited by the uncertainty principle, then the possibility of a space-time description of physical phenomena must be correspondingly restricted. If only one point can be observed of the orbit of an electron moving in an atom in a stationary state, then the very idea of orbit obviously loses its meaning. No space-time description of atomic transition processes, and hence no visualization, is possible. Thus the kinematics of the quantum theory must be radically different from that of ordinary mechanics. It has been claimed that even if an exact space-time description of atomic processes is impossible, still each electron must obviously have a definite position at any moment. But this demand for what Whitehead calls simple loca-

tion is no more valid than the belief in absolute motion after the adoption of the theory of relativity.

The faith of the old physics in simple location is called by Whitehead the fallacy of misplaced concreteness. The recognition of this fallacy is obviously of the utmost importance for the general theory of knowledge.

The renunciation of the belief in simple location has an interesting consequence. In his "Allgemeine Erkenntnislehre" Schlick sets up the following criterion of reality: real is everything which must be conceived of as existing at a definite time. Now if no space-time description of the atomic processes is possible, these processes would be deemed unreal according to Schlick. His criterion of reality, which otherwise seems too broad, hence needs revision if real existence is to be attributed to the electrons within the atoms.

The limitation imposed upon any space-time description by the principle of uncertainty has completely removed the dilemma concerning the structure of light and matter. Both the particle picture and the wave picture have only a limited validity and, as Bohr has shown, their limitations are such as to exclude any contradiction between them. To the extent that a space-time description is possible, both concepts are perfectly equivalent.

The most interesting philosophical implication of the principle of uncertainty is its bearing upon the principle of causality. This latter principle, which was so strongly supported by classical physics, has come to be regarded as almost self-evident like the axioms of Euclidean geometry. The traditional belief in the exalted position of the principle of causality is well exemplified by the following statement by the German mathematical physicist G. Mie. He writes in the first volume of Müller-Pouillet's "Lehrbuch der Physik," published in 1929:

> Thus we may compare the entire picture of the world which physics has constructed with a network of artfully woven threads, of which causality is the cohesive force. If the connection would be severed in a single mask, the entire weave would come apart. To sacrifice even the smallest iota of the principle of causality would mean to give up physics.

Now the principle of causality states that if an isolated part of the universe were known with perfect accuracy at a given instant, then it should be possible, at least in principle, to predict any future event within this part of the world. But according to the principle of uncertainty, the state of no part of the universe can be known with perfect accuracy. Not even the state of a single atom, or even of a single electron, can be fully known. In fact, if half of the quantities required for specifying the state of a given system were known with perfect accuracy, we should be completely ignorant of the values of the other half of the required quantities. The principle of causality, as formulated, is therefore not valid. The belief in strict or rigorous causality must be given up. Of course, it may be maintained that the world may well be ruled by determinism and that the principle of causality may well hold even if our limitations are such that we can not accurately check this determinism. But in this interpretation the principle of causality would be meaningless. For a statement ceases to have meaning when it is recognized that no criterion exists for testing its validity.

It is necessary to analyze the matter a little more closely. The principle of causality applies to isolated systems, but whenever a system is being observed it is no more an isolated system. Causality and observation thus mutually exclude one another. Bohr, to whom our present understanding of the uncertainty principle is largely due, speaks about a fundamental complementarity between causality and the possibility of observation and hence of space-time description. The principle of causality is implied whenever we make use of the laws of the conservation of energy and momen-

tum, and in such cases a space-time description is out of question. The claim of causality may also be said to be satisfied as long as we describe a phenomenon by means of the abstract mathematical machinery of the quantum theory, but the equations contain the time and the space coordinates in a purely formal manner and furnish no space-time description. Such a description, obtained when the results of the computations are given a physical interpretation, always implies observation and hence a break in the causal chain.

It is an interesting feature of the quantum theory, first recognized by Born, that its statements, when interpreted physically, must be considered as having only statistical significance. In this regard the laws of the quantum theory are much like the laws of thermodynamics or like Mendel's laws in genetics. A statistical law gives only probabilities and average values. The accuracy of its predictions depends entirely upon the number of individuals in the group considered and upon the length of time the group is observed.

Now the laws which are found to hold for matter in bulk, in particular the laws of ordinary mechanics and electrodynamics, must evidently be regarded, in spite of the theory of emergent evolution, as consequences on the laws holding for single atoms or for small groups of atoms. It seems, therefore, that all known physical laws are of statistical nature. We may, therefore, well raise the question: Is statistical truth the only kind of truth which we may strive for? And we may ask: Are statistical laws possible without primary laws? It would seem that any statistical regularity must depend upon some sort of similarity in the behavior of the individuals. If this similarity in behavior is not a primary law it must presumably be statistical, but then it would depend upon some more fundamental regularity, which in turn might be either statistical or primary, and so on. We shall not attempt to answer these questions. It may well be that the very distinction between primary and statistical law is a fallacy.

The application of the laws of the quantum theory to physical problems is often very difficult. Not only do we have a choice between two space-time pictures, that of a particle and that of a wave, whose limitations must be constantly kept in mind, but there is, in addition, a wide ambiguity as to the differentiation between the object to be observed and the instrument of observation. Thus, in the idealized experiment described above in which the position of an electron is determined by observing the light it scatters, we may consider either the electron alone, or the electron and the light, or the electron, the light and the microscope as the object to be observed. Or we might even include our eye and part of our nervous system. In principle, it makes no difference how we delimit the object, but of course the mathematical machinery of the quantum theory must be applied in accordance with the choice we make. Obviously, we need to develop new concepts and mental habits which conform to the requirements of the quantum theory, for we are continually apt to be deceived by the traditional scientific thought with its union of causality and space-time description.

The strange implications of the theory of relativity and of the quantum theory may be disregarded by many experimental physicists who deal with slow motions and with large-scale phenomena, but for the epistemologist these implications are of the utmost importance. The theory of relativity has already had a profound influence upon contemporary scientific thought, and it is clear that Bohr's conception of a complementarity between space-time description and causality, based upon Heisenberg's principle of uncertainty, will have a central place in any future theory of knowledge.

THE GASEOUS EXPLOSIVE REACTION[1]

By Professor F. W. STEVENS

PHYSICIST, UNITED STATES BUREAU OF STANDARDS

THE extensive application of the gaseous explosive reaction as a source of power in internal combustion engines has given every one at least some acquaintance with it in its present popular rôle; for in this rôle it occupies a large part of the world's stage, proclaiming in modern noisy, spectacular fashion to crowded houses its latest contribution to the secondary environment within which, above, below and all around, human life is rapidly enclosing itself.

This particular application of one of the commonest forms of molecular transformation to be met with—a transformation wholly confined to the gaseous state at the high temperature of flame—has been from earliest times perhaps more intimately associated with human life than any other of nature's forces.

The longest well-developed road we know is that leading from the primitive engineer who first built his fire at the mouth of a cave to gain the advantage of its heat in the bodily comfort of warmth, to the modern engineer who now builds it within the engine's cylinder to gain the advantage of its heat in the control and direction of power. Yet the primitive engineer in building his fire was concerned with the same general technical problems as the modern engineer: Both selected their fuel from nature's store with care based on trial and experience; both were concerned with the problem of ignition and with its position, relative to the fuel, where it would be most effective; both estimated, then apportioned, the amount of fuel to meet the required end, and both were particularly concerned in controlling the period of its transformation.

If in general the broad technical problems that have so far arisen in the various applications made of the flame reaction have changed but little over this long period of development, the changes that its multiplying applications have wrought in the environment of those devising and using them, together with the changes compelled by the reaction of that modified environment on intellectual development and outlook, form a record of basic human interest. Such a record of any line of development exhibits the interrelation between what is termed human progress and the products, material and intellectual, of that progress that provide the equipment necessary for effecting the next advance.

Whoever has followed the history of a single science finds in its development a clue to the understanding of the oldest and commonest processes of all knowledge and cognizance.[2]

Historical studies are of fundamental importance in connection with the effort to advance scientific knowledge in any line. It is from such studies that we became acquainted with other problems, other possible assumptions, other viewpoints whose birth, growth, change and decay were connected with the conditions under which the processes then studied took place. Under the influence of other facts which once occupied the front of the stage, there arose other concepts than those today in vogue; from these we may observe that ever new problems arose to demand solution. If we accustom ourselves to consider every concept simply as a means to a definite end, we likewise accustom ourselves in any particular case to tolerate in our own mode of thinking those changes that the facts seem to require.[3]

That part of the development of knowledge pertaining to the flame that

[1] Publication approved by the Director of the Bureau of Standards of the U. S. Department of Commerce.

[2] Nietzsche.

[3] E. Mach.

is most intimately connected with its present extensive application as a source of power, is of rather recent acquisition—paralleling closely industrial development that is dependent on the efficient use of power. It might be mentioned, however, that the long slow development previous to the industrial era is by no means devoid either of technical or of human interest. The specialist in folklore finds the flame intimately connected with the life of the home, while the traditions of alchemy still abundantly persist. With the passing of the hearthstone, passed many of the traditions, industries and influences of home life—the essential matrix that insured the solidarity of the older state. Besides, it was during this long period of companionate intimacy with the family that the flame firmly established itself as a powerful mystic symbol of life. It inspired contemplation on the ancient altar, it still provokes humility and reverence on the modern one. These human reactions may not be ignored in modern research, for, given time enough, the concepts born of the science of any period ultimately become a lore.

Diffusion Flames

The realization of the fact that the common flame—no matter what may have been the crude form of the fuel used—burned only gas, developed with extreme slowness; but when fully realized, quick advantage was taken of it in the manufacture and piping of "distilled coal" from a central works. This gas was at first largely produced and consumed for lighting purposes in fishtail burners. Like the primitive flame that it was, the flame in this case depended for its support on the mutual rate of diffusion between the fuel-gas and the air. Between the layer of pure gas on the one hand and pure air on the other, there existed regions of every possible mixture ratio of fuel-gas and air. Not all these mixture ratios would support a flame reaction and only one of them would support the reaction without loss to either reacting component. The economic possibility occurred to Bunsen of effecting the complete diffusion of the active gases, before ignition, in any desired mixture of gas and air or of gas and oxygen. The original simple device developed to secure this advantage—the Bunsen burner—made a new and highly efficient flame form possible while incidentally solving the smoke prevention problem. Numerous modifications of Bunsen's device suitable to different industrial purposes have rapidly followed. In magnitude this application by industry of the continuous gaseous explosive reaction rivals its application as a source of power in the gas engine.

The Zone of Explosive Reaction

When a homogenous mixture of explosive gases is fed through a tube at a constant volume rate of flow and ignited, the characteristic form assumed by the flame is no longer diffused but is confined to a thin, sharply defined stratum or zone within which the explosive transformation of the gases takes place. The reaction conditions automatically maintained by the continuous uniform flow of the homogenous mixture of explosive gases is therefore constant. Fig. 1 (p. 561) is a photograph of the stationary explosive reaction zone formed above the burner tube. Fig. 2 is a schematic diagram of it. This device in its most refined form and accurate manipulation provided the first opportunity for studying at least the gross mechanism of the gaseous explosive process. Gouy (1879), in carrying out his photometric investigations of colored flames, using a modified Bunsen burner, realized that this stationary figure of the reaction zone so closely approaching a perfect cone could, under

favorable conditions, be analyzed in terms of the relative movement between zone and active gases supporting it. He found that if u was the uniform linear rate of flow of a filament of the explosive gas issuing from the tube and entering the zone at an angle α, then the component of u normal to the surface of the zone would just balance the linear rate of propagation of the zone within the gases. He further found that any change in the velocity of u was followed by such an automatic readjustment of the symmetrical conical figure, and hence of the angle α, that the linear rate of propagation of the reaction zone for a given explosive mixture remained constant. Gouy's results may be stated as follows: *The linear rate of propagation of the reaction zone relative to a homogeneous mixture of explosive gases is constant at constant pressure and independent of the mass movement of the active gases supporting the zone.* Gouy's experimental results, dealing with the gross mechanism of the gaseous explosive reaction at constant pressure, were, as stated, incidental to his investigation of colored flames. They have remained for a long time obscure.

In the meantime unusual interest and activity developed in the study of the gaseous explosive reaction under constant volume conditions. Under these conditions the observed rate of displacement of the zone in space is far from constant. The initial pressure and temperature of the active gases passing the reaction zone during the progress of the explosion is likewise variable; also the essential factor—the mass movement of the active gases supporting the zone, determinate, at least approximately, by Gouy's method, is indeterminate under constant volume conditions. As a consequence, *the linear rate of propagation of the reaction zone relative to the active gases carrying it, i.e., their linear rate of transformation, can not be determined under constant volume conditions, because the mass movement of the gases carrying the zone is indeterminate.*

But the study of gaseous explosions in closed containers, nevertheless, led to important results. In 1883 Berthelot and Vieille announced the discovery of a new gross mechanism of the explosive reaction. This they designated as the explosive wave.

> As soon as the compression of the unburned layer of gases in the container becomes so great that self-ignition follows, the resulting extraordinary powerful compression wave is propagated with very great velocity and with simultaneous ignition; *i.e.*, we have the spontaneous development of the explosive wave.[4]

The pressure within the wave is constant; its rate of propagation is constant and characteristic for each mixture ratio; it is independent of initial pressure and of the container. For purposes of study, the wave has usually been incited in explosive mixtures by the development within long cylindrical containers of those pressure-temperature conditions necessary to its formation and continuation. It was discovered in connection with the normal burning reaction. It is not, however, dependent on this preliminary stage. Any means of producing in the explosive gaseous fluid a compression wave intense enough to ignite the gases will incite the explosive wave form of reaction in those mixtures able to support it. The propagation of the explosive wave is usually looked upon as a purely hydrodynamic process into which the molecular transformation enters only as a thermodynamic factor, the heat of reaction. Nernst has expressed the opinion that molecular theoretical consideration introduced to explain explosive wave phenomena are as much out of place as they would be for the treatment of acoustics. Nevertheless the modern theory and mechanism

[4] Nernst.

involved in the kinetics of chain reactions seem to offer quite as favorable an explanation of the phenomena as purely hydromechanical considerations. In reference to the various special theories that arise from time to time, resulting from studies of special reaction forms, it should be appreciated that the different reaction forms that the same gaseous molecular transformation may assume all lead to the same final equilibrium condition, K, for the same final temperature and pressure. The transition from one form to another is abrupt and outwardly definitely marked. It is assumed, however, since each of these forms leads to the same end point, that the ultimate microprocesses (if "ultimates" exist) in each of them are the same; yet no satisfactory theory and mechanism describing these microprocesses and at the same time accounting for the abrupt changes in reaction rates that characterize the different forms have as yet appeared.

As far as industrial applications of the reaction as a source of power are concerned, experience shows that only its normal burning form is applicable. Both in engine design and in preparation of fuel it is sought in practice to confine the reaction strictly to its normal burning form; yet the study of this important form has received far less attention than that of the slow reaction below ignition temperature and much less consideration than the explosive wave (detonation) or even its electrochemical form occurring in the gas cell.

With very few exceptions, all the studies of the normal burning gaseous reaction have been made under conditions of constant volume. A survey of the great number of such studies dealing with the behavior of the reaction zone will show, however, that the observed time-displacement of the zone in space has erroneously been considered its rate of propagation within the gases. The rate of displacement of the zone in space is the sum of its rate of propagation relative to the gases plus the rate of mass movement of the gases carrying it. In the case of the reaction at constant pressure, the rate of mass movement of the gases is always numerically much greater than the rate of propagation and this is true also for the initial stages of the reaction under conditions of constant volume. Perhaps the necessary distinction between the rate of displacement of the reaction zone in space and its rate of propagation relative to the active gases carrying it may be made clearer by considering the case of a man walking at uniform rate along a moving train of box-cars. In order to find his rate of progress (propagation) relative to the train (gases) from his observed rate of displacement in space, the simultaneous movement of the train (gases) must be known. The train (gases) may slow down, go faster, stop or back up (it does all this and worse in a few thousandths of a second under constant volume conditions), while the movement of the man (zone) relative to the train (gases) remains constant. Helmholtz and Kundt pointed out this error in the earlier results published on the behavior of the normal burning reaction zone, and at their instigation Michelson (1889) carried out a set of studies to determine the normal rate of flame propagation in mixtures of explosive gases. Michelson found for the normal burning reaction zone, as did Berthelot for the explosive wave, that each explosive mixture, at constant pressure, had its own characteristic rate of propagation—the explosive wave values for the same reaction being some thousand times higher than the corresponding values of the normal burning zone. Michelson plotted the results he obtained, expressing velocities as ordinates and the volumetric mixture ratios as abscissae. By so doing he found that the resulting graphs in all cases indi-

cated a smooth curve with maximum at or near the velocity corresponding to equivalent proportions of the reacting components. The most complete and definite set of results obtained by him were those for the explosive reaction of carbon monoxide and oxygen. The explosive reaction of these gases saturated at room temperature with water vapor, is relatively slow, while the actinic property of the reaction zone is most favorable for securing photographic records of it.

It was Michelson's coordinate figure expressing the experimental relation between the rate of propagation of the reaction zone measured relative to the active gases (their linear rate of transformation) and the volumetric mixture ratios of those gases that led the writer to suspect a possible statistical relation between the linear rate of propagation of the zone within the gases and their molecular concentrations—a relation analogous to that offered by Arrhenius between the rate of molecular transformation, V, and the partial pressures of the active gases. $V = k_1[A]^{n_1}[B]^{n_2}[C]^{n_3}\ldots\ldots\ldots$ is Arrhenius's expression for the rate of molecular transformation in one direction of a gaseous system, where [A], [B], etc., are the partial pressures of the various active gases, n_1, n_2, etc., their respective coefficients in the stoichiometric equation written for complete reaction; $n_1 + n_2 +$ etc. is the assumed reaction order. k_1 is a proportionality factor termed a velocity coefficient. In the case of the gaseous reaction $2CO + O_2 \rightarrow K$, Arrhenius's generalized expression becomes $V = k_1[CO]^2[O_2]$. In this expression for molecular transformation, the writer substituted for V the experimental values for the linear rate of propagation, s (transformation), found by Michelson, and for the bracketed expressions, the partial pressures of CO and O_2 corresponding to s. At constant pressure the concentrations of the active gases entering the zone remain constant; hence s should remain constant, as it does. $k_1 = \frac{s}{[CO]^2[O_2]}$ states how much greater the numerical value of the linear rate of propagation is than the numerical value of $\Gamma = [CO]^2[O_2]$ giving the probable rate of impacts in an assumed trimolecular order, $2CO + O_2$, finally resulting in an equilibrium condition, $K = \frac{[CO_2]^2}{[CO]^2[O_2]}$. The equation $s = k_1[CO]^2[O_2]$ has its maximum value when the partial pressure of CO = .667 and O_2 = .333. This is close to the experimental value found by Michelson. Using all of Michelson's experimental values, it was further found that k_1 remained fairly constant. Much closer agreement was later found by repeating and greatly extending his experimental studies. In so doing, however, a number of disadvantages not easily overcome were revealed in the burner method. In only those cases where the stationary form of the reaction zone approached closely a symmetrical cone was the agreement found satisfactory. The distribution of flow velocities over the cross-section of the tube is, in most cases, far from uniform, while the assumption that their rate and direction of flow after leaving the aperture of the tube remains parallel to its axis will not hold; especially is this found to be the case where high flow velocities through the tube are necessary to balance the high rates of propagation of the reaction zone met with in many gaseous explosive mixtures. The method has very narrow limitations; it is only approximate in those cases where an assumption of uniform flow both within and without the burner tube may not be greatly in error. Fig. 7 shows the close agreement between observed and calculated values of s in this reaction when some of the

disadvantages of the burner method have been overcome.

The Spherical Bomb of Constant Volume with Central Ignition

In seeking some means whereby the actual rate of propagation of the zone relative to the active gases (their linear rate of transformation in a gaseous system) could be distinguished from the simultaneous mass movement of the gases, a number of controlling and directive principles already well established played a determining part. Chief among these were two thermodynamic methods, one theoretical, the other experimental, but both offering interesting suggestions as to the behavior of the reaction zone in explosive transformations. The theoretical mechanism made use of by van't Hoff and others in computing the maximum work of a gaseous transformation employs three imaginary zones or compartments corresponding to three important stages in the reaction over which by a cycle process the maximum work of the transformation is computed. This imagined process involves the concept of a continuous uniform reaction maintained in the reaction chamber by supplying it with initial active components *at the same uniform rate* at which the reaction (equilibrium) products were removed to the equilibrium zone. Now the gaseous explosive reaction automatically falls into the same three well-marked zones and at constant pressure actually executes the imagined process described by van't Hoff of supplying its reaction zone with initial active components at the same constant rate that the reaction (equilibrium) products are removed from it. The other thermodynamic method involving the behavior of the reaction zone, was a purely experimental one in which it is evident that the high degree of accuracy attained during the last twenty years by its use depends on the inherent

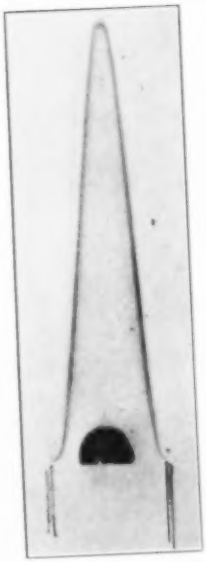


Fig. 1

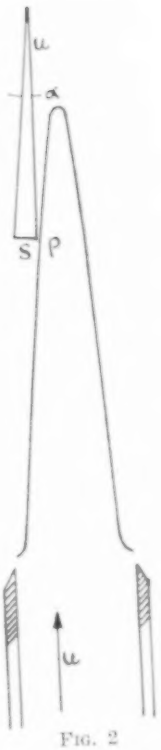


Fig. 2

characteristics of the reaction zone in effecting the transformation of a gaseous system. The new principle introduced with so much advantage in these thermodynamic studies is the old principle of symmetry. Langen, an automotive engineer, engaged on studies of the gas engine with the ultimate purpose in view of establishing for it a rational thermodynamic cycle of reference, realized clearly that the movement of the normal burning reaction zone as observed in space was made up at all times of the rate at which the zone propagated itself relative to the active gases carrying it and the mass movement of the gases themselves. Realizing this he further saw that if the explosive reaction in homogeneous gases originated at the center of a spherical bomb of constant volume, then the reaction zone together with the hydrodynamic disturbances set

FIG. 3

up in the homogeneous fluid at the same point must all maintain, during the transformation, positions concentrically symmetrical with the ignition point and with the spherical bomb. In this way the heat losses, large and indeterminate in the engine cylinder—or in any other form of container—during the progress of the explosion would, by this application of the principle of symmetry, be reduced to unavoidable losses due only to radiation. Such insight on the part of Langen, having regard both to the dynamics of the engine's fluid and to the consequent favorable symmetry of all of the processes occurring in it, has developed into an instrument of high precision—an instrument and method inspired by the demands of industry, serving most efficiently both practical and theoretical ends.

A specially high value must be attached to the explosion method, since, by suitable variations of the experimental conditions, it enables both the specific heats and the equilibrium constant to be determined.[5]

THE SPHERICAL BOMB OF CONSTANT PRESSURE WITH CENTRAL IGNITION

In the light of historical development—from the lead of the well-traveled road—it would be difficult to escape the suggestion so evident in the constant pressure method of Gouy-Michelson, in the theoretical vision of van't Hoff's cycle and in the constant volume method and device of Langen, that, if a volume of homogeneous explosive gases at rest and without diffusion could exist temporarily in space, a reaction zone originating at a point within would propagate itself in the homogeneous gases at a constant rate in all directions; it would be an expanding sphere enclosing the reaction (equilibrium) products. The idea suggested itself that a close approach to this ideally favorable but practically unattainable condition could be to a fair degree realized by holding temporarily the explosive gaseous mix-

[5] Nernst.

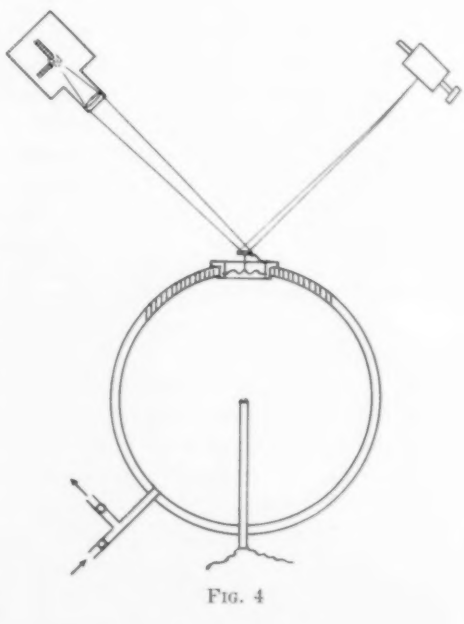


FIG. 4

ture within a soap film container and firing it from the center. Fig. 3 is a photograph of such a container holding temporarily an explosive mixture of carbon monoxide and oxygen. Fig. 4 is a schematic figure of Langen's spherical constant volume bomb with central ignition. Fig. 5 is a photographic time-volume record of the reaction that followed ignition of the gases in the soap film bomb. Fig. 6 is a time-pressure record of the reaction, obtained with a Pier manometer, that followed ignition in Lange's spherical constant volume bomb. These two sets of figures, the one expressing the initial and final volumes at constant pressure, the other expressing the initial and final pressures at constant volume, are thermodynamically related as expressed in the gas law, $pv = nRT$. The final pressure corresponds to the reaction constant K_v; the final volume, to the reaction constant K_p.

Fig. 5 permits the sought-for distinction to be made between the actual rate of propagation, s, of the reaction zone and the rate of mass movement of the active gases carrying it. The time-displacement trace of the zone on the moving photographic film is a right line. The speed of the film and the rate of displacement of the zone at right angles to each other were constant; hence the inclination of the zone trace on the film gives the rate of displacement of the zone in space, s′. The initial volume of the explosive gases whose transformation is here considered and whose time-volume change is automatically recorded in Fig. 5 is the volume of a sphere whose initial diameter is 2r—the horizontal diameter of the bubble passing through the point of ignition. The bubble itself is not a sphere, but the reaction zone originating at the point of ignition is a sphere and remains so during the transformation of the gases. The volume of this expanding sphere at the instant all of the gases of the initial sphere, 2r, have been transformed, is given by its final diameter, 2r′, recorded in the photographic time-volume figure. From these dimensions the rate of propagation of the zone relative to the active gases (their linear rate of transformation) may be found. It is $s = s' \frac{r^3}{r'^3}$. The rate of mass movement of the active gases away from the ignition point is, for the condition of constant pressure here described, $s' - s$.

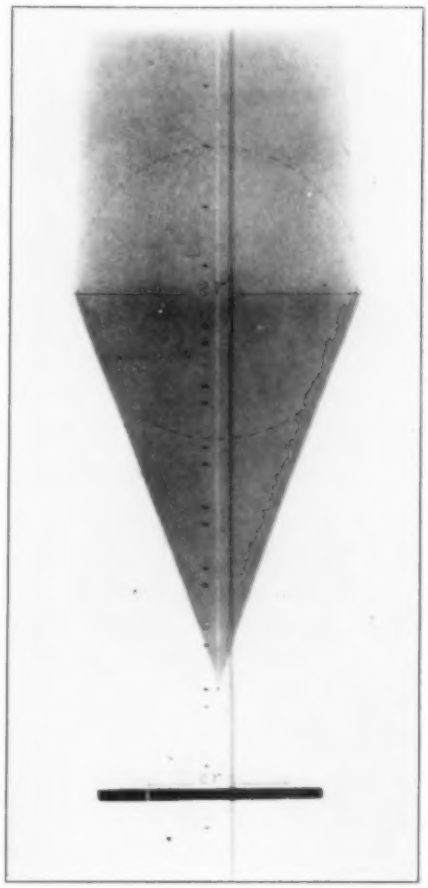


FIG. 5

The simple bubble device, functioning as a transparent bomb of constant pressure, is the complement of the bomb of constant volume; it duplicates all of the thermodynamic possibilities of that

bomb, dispenses with a manometer, and avoids the unfavorable violent disturbances of the gaseous fluid inseparable from the explosive reaction at constant volume. Being transparent, it provides in addition an accurate method for determining, under standard conditions, the rate of propagation of the reaction zone relative to the active gases. For this purpose it is applicable to a very wide range of reaction velocities below the velocity of sound in the gases. With this device the empirical statistical relation, indicated in Michelson's published results, connecting the rate of propagation of the zone with the concentration composition of the active gases, was tested out: $s = s' \frac{r^3}{r'^3} = k_1 [CO]^2 [O_2]$. The results that were obtained are shown in the coordinate Fig. 7. Experimental values are represented in the figure by filled circles. Open circles and the continuous link mark the locus of the equation, $s = 691 [CO]^2 [O_2]$. The constant, 691, is the average value of $k = \frac{s}{[CO^2][O_2]}$ over the range of mixture ratios that would support a reaction zone. The agreement here between observed and calculated values is seen to be close.

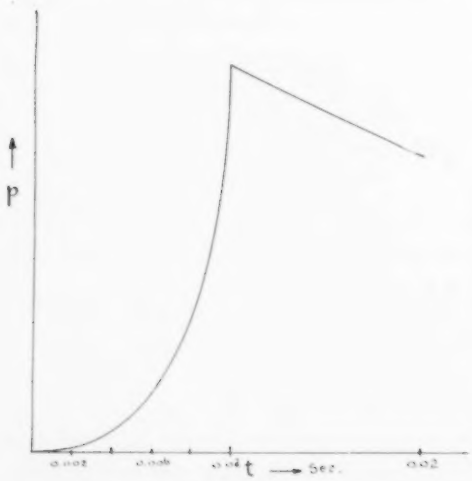


FIG. 6

The stoichiometric equation expressing the equality of masses between the initial components and the reaction products, together with the reaction heat of the transformation, provide the fundamental thermodynamic factors available to the engineer. In the value of K they express for any given condition of temperature and pressure the reaction constant—the essential factor in determining the maximum work of the explosive reaction, A (van't Hoff's reaction cycle). In its simplest form, this may be expressed as $A = RT \ln K$. Should a relationship of the same factors express also the rate of energy liberation in the same gaseous explosive charge, their practical utility would be much extended as well as their theoretical significance. During the last few years the relationship shown in the coordinate Fig. 7 has been tested in the case of a great many other gaseous explosive combinations; in all of these cases the relationship between rate of propagation and the concentrations of the active components was found to hold wherever the stoichiometric equation could be written for the completed reaction. The details of these studies and their specific results can not be given here. They involve not only simple gases such as the example given, but fuels of complex composition also, made up of known components in known proportions; and the effect of inert gases. Reactions have also been studied over wide ranges of different constant pressures and the effect of pressure on the rate of propagation of the reaction zone and the rate of molecular (energy) transformation within it, determined. When the reaction takes place at constant volume the unburned active gases may be progressively subjected to pressures varying, say, from one to ten or

more atmospheres in a very small fraction of a second. The reaction period is so short that the instant effect of the rapidly increasing pressure on the rate of propagation of the reaction zone and on the rate of molecular transformation within it becomes practically impossible to determine. But by the constant pressure method described, the instant pressure corresponding to any stage in the progress of the constant volume reaction may be duplicated and indefinitely maintained so that the effect of the pressure on the rate of propagation of the reaction zone for all mixture ratios of the given fuel that will ignite may be readily measured. The results of these special studies, carried out at the Bureau of Standards at the request of and with the financial support of the National Advisory Committee for Aeronautics, may be found in the committee's Technical Reports.

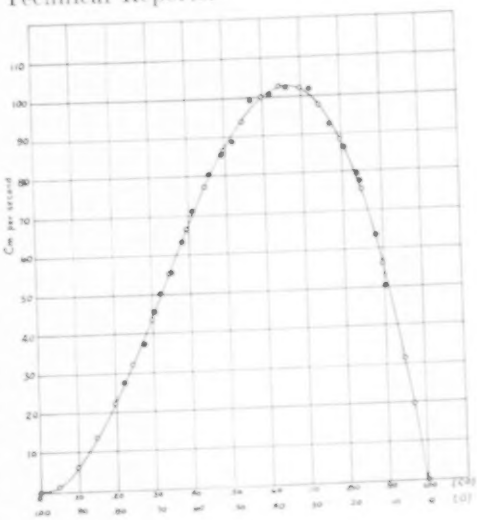
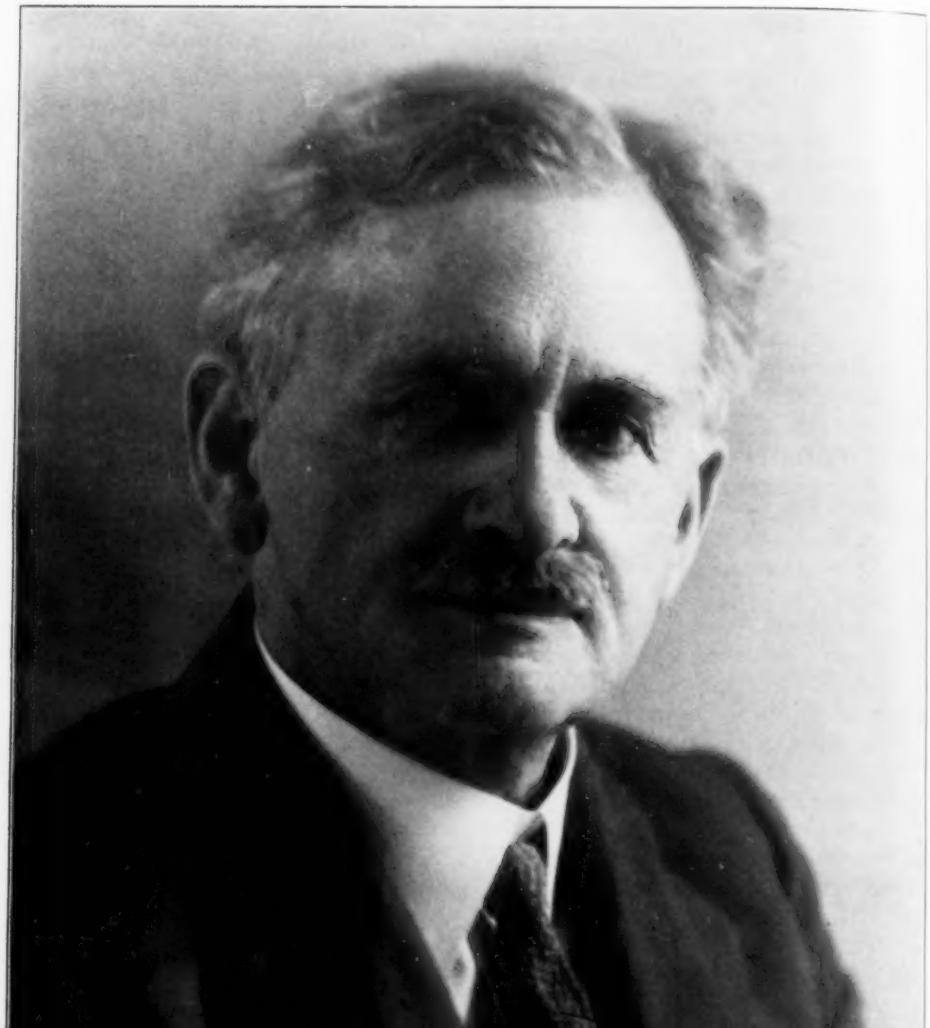


FIG. 7



ALBERT ABRAHAM MICHELSON

LATE DISTINGUISHED SERVICE PROFESSOR AND HEAD OF THE DEPARTMENT OF PHYSICS OF THE UNIVERSITY OF CHICAGO, WHO DIED IN PASADENA ON MAY 9.

THE PROGRESS OF SCIENCE

THE FRANKLIN MEDAL AWARDS OF THE FRANKLIN INSTITUTE

THE Franklin Medal, the highest award in the gift of The Franklin Institute, is awarded annually to those workers in physical science or technology, without regard to country, whose efforts, in the opinion of the institute, acting through its committee on science and the arts, have done most to advance a knowledge of physical science or its applications.

This year two Franklin Medals have been awarded and were presented to the recipients at the Medal Day Exercises at The Franklin Institute on the afternoon of Wednesday, May 20.

One of these awards was presented to Sir James Hopwood Jeans, of London, England, in recognition of his many fruitful contributions to mathematical physics, especially in the realms of the dynamical theory of gases and the theories of radiation, of his challenging explanations of astronomical problems and of his illuminating expositions of modern scientific ideas.

Sir James Jeans was born in London in 1877, was educated at Trinity College, Cambridge, where he was second wrangler in 1898 and Smith's prizeman in 1900. Mention of some of the positions he has held will show the influence he has been in the field of scientific education. He was professor of applied mathematics at Princeton University from 1905 to 1909, Stokes lecturer at Cambridge from 1910 to 1912, Halley lecturer at Oxford in 1922, associate at Mt. Wilson Observatory in 1928 and secretary of the Royal Society.

He has been the recipient of many honors—a Royal Medal from the Royal Society in 1919, the Gold Medal of the Royal Astronomical Society in 1922. He is a fellow of the Royal Society and of Trinity College and was knighted in 1928.

He has been a leader in the advances that have been made in the fields of the physical sciences, notably in astronomy. That this is so may be seen by a consideration of the many books that he has published: "The Dynamical Theory of Gases" in 1904, "Theoretical Mechanics" in 1908, "The Mathematical Theory of Electricity and Magnetism" in 1908, "Radiation and the Quantum Theory" in 1914, "Problems of Cosmogony and Stellar Dynamics" in 1919, "Atomicity and Quanta" in 1926, "Astronomy and Cosmogony" in 1928, "The Universe Around Us" in 1929, "The Mysterious Universe" in 1930 and "The Stars in Their Courses" in 1931.

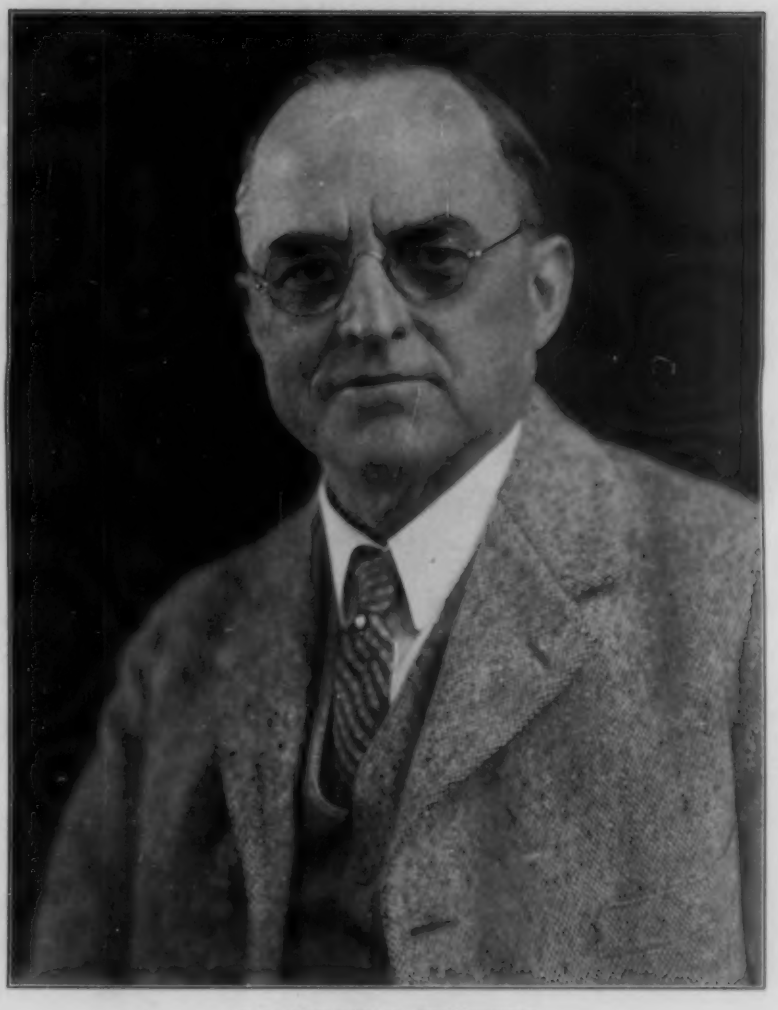
While a number of these books are highly technical and can be read with full understanding only by those having a scientific education the later books are of a more popular character. This is especially true of "The Stars in Their Courses," which is an expansion of a series of radio talks given through the British Broadcasting Company. The book puts in an attractive and readily understood fashion the story of what constitutes the universe as it is understood by one who has made the subject a lifelong study. Sir James has made many contributions to the growth of science, as is shown in his many papers published in scientific journals.

Another medalist for 1931, to whom the Franklin Medal was awarded, is Dr. Willis Rodney Whitney, of Schenectady, New York, in recognition of his valuable contributions to industrial chemistry and of his signal success as organizer and director of the greatly productive research laboratory of the General Electric Company, a success due in large part to his appreciation of the potential value of pure research in

SIR JAMES HOPWOOD JEANS

invention and industry, to his judgment of men and to his generosity in dealing with them.

Dr. Whitney's birthplace was Jamestown, New York, in 1868. He was graduated from the Massachusetts Institute of Technology in 1890 with the degree of S.B. and received the degree of Ph.D. from the University of Leipzig in 1896. From 1890 to 1904 he was engaged in educational work, serving as an investigator and a teacher in the department of chemistry of the Massachusetts Institute of Technology, where he advanced by regular steps from assistant instructor to assistant professor and now holds the position of non-resident professor of theoretical chemistry in that institution. His present position is that of director of the Research Laboratory of the General Electric Company, at Schenectady, New York. He received the honorary degree of Sc.D. from Union University and that of Ch.D. from the University of Pittsburgh. In 1916 Dr. Whitney was awarded the Willard Gibbs Medal by the American Chemical Society; in 1920 the Chandler Medal by Columbia University, and in 1921 the Perkin



DR. WILLIS R. WHITNEY

Medal by the American Section of the Society of Chemical Industry.

Dr. Whitney is a member of many societies, among them being the National Academy of Sciences, the American Chemical Society, of which he was president in 1910, the American Electrochemical Society, the American Institute of Mining and Metallurgical Engineers, the American Institute of Electrical Engineers and others. He is a fellow of the American Academy of Arts and Sciences. He holds many important positions, among which are: Member of the United States Naval Consulting Board since 1915, was a member of the Advisory Committee of the United States Bureau of Standards, and is a member of the National Research Council.

At the Medal Day exercises of the Franklin Institute fifteen medals which had been awarded during the institute year were presented to their recipients or representatives of them. The medalists were drawn from four foreign countries as well as from the United States, two coming from England and one each from Canada, Japan and Germany.

JEAN BAPTISTE JOSEPH FOURIER

THE DISTINGUISHED FRENCH MATHEMATICIAN, THE CENTENARY OF WHOSE DEATH WAS CELEBRATED LAST YEAR.

THE PASADENA MEETING OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, JUNE 15–20, 1931

CALIFORNIA offers a most appropriate setting for the first of a new series of summer meetings to be held by the American Association for the Advancement of Science, for of all our forty-eight states it offers the best field for research work in every branch of science.

The clear skies and dependable weather of many sections of the state are especially favorable for investigations in astronomy and astrophysics, while the mild and equable temperatures are ideally suited to all types of laboratory work—in physics, in chemistry and in biology.

The fauna and flora of the state are of astonishing richness, and thanks to the great mountains are wonderfully diversified. Not only are characteristic American animals and plants well represented, but many Asiatic types may here be studied in the higher altitudes. To the student of marine life the Pacific coast offers a wealth of material a surprisingly large part of which is nowhere else available.

Opportunities for work are one thing, but vision enabling one to see those opportunities and ability to make use of them is quite another thing. Vision and resourcefulness have been happily combined with enterprise in making use of the unusual advantages to be found in California.

The vigorous and healthy growth of the scientific spirit in the West has been due in no small measure to the emancipation from that conservatism and conventionalism which until rather recently fettered our educational and scientific institutions in the East. But while casting off the fetters of extreme conservatism, the early settlers in California at the same time brought with them the seeds of the essentials of cultural development, which were planted in fertile virgin soil.

This was made possible by the rapid and complete eclipse of the Spanish influence—which was never very strong—before the invasion of the vigorous new blood coming from the East.

It may be recalled that the history of modern California began in March, 1848, when the territory was ceded to the United States by Mexico. The acquisition of California was itself to a certain extent the outcome of scientific exploring expeditions headed by General John Charles Frémont—the "Pathfinder"—and carried out in 1842, 1843–'44, 1845 and 1846–'47.

In the Constitutional Convention held in 1849, California incorporated into her fundamental law recognition of and provision for a state university.

On January 12, 1777, two Franciscan padres, de la Pena and Murguia, had planted the mission cross at Santa Clara, and in 1851 Santa Clara College was established to save the mission, and also to start a college to meet the growing needs of the times. This institution was chartered as a university on April 28, 1855.

The College of the Pacific was established at Stockton in 1851, Mills College was founded at Oakland in 1852, Contra Costa Academy (later College School) was founded at Oakland in 1853, and in 1855 St. Ignatius College was established in San Francisco.

The University of California was established in 1868 as a result of three separate movements—one originating in state action, one in federal action, and one in private initiative.

Following the recognition of the desirability of a state university by the Constitutional Convention in 1849 there had been constant public agitation for making effective provision for such an institution. Federal action began in 1853 when Congress gave the state

46,000 acres of land for a "seminary of learning."

Private action owed its inception to the foresight of the Rev. Henry Durant. In 1853, under the auspices of the Presbytery of San Francisco and of the Congregational Association of Oakland, Mr. Durant opened in Oakland the Contra Costa Academy, but soon changed the name to College School in order to signify that the undertaking was only preparatory to a projected college. In 1855 such an institution was incorporated under the name of the College of California.

The instruction was given in buildings in Oakland, but in 1856 a tract of land five miles to the north was secured, and the college buildings were begun. In 1860 the college was opened.

In 1862 a further impulse was given the movement for a state university by the passage by Congress of the Morrill act for the establishment of an agricultural, mining and mechanical arts college.

In 1867 the three separate forces began working together to one end—the establishment of a University of California. The private enterprise known as the College of California contributed its buildings and four blocks of land in Oakland, together with its 160 acres of land in Berkeley; the federal government the Congressional gift of 150,000 acres of public lands; and the state its property accumulated for the purpose, together with new legislative appropriations. The legislative act creating the University of California was signed by the governor on March 23, 1868, and the new institution opened its doors for instruction in September, 1869.

The University of Southern California was founded at Los Angeles in 1880.

In March, 1881, the legislature of California created the Los Angeles State Normal School. Five acres of ground were donated at the corner of Fifth Street and Grand Avenue—the present site of the Los Angeles City Library—and the corner-stone of the first building was laid on December 17 of that year. Instruction began in August, 1882.

Through legislative action made effective by the governor's signature on July 24, 1919, the grounds, buildings and records of the Los Angeles State Normal School were transferred to the regents of the University of California, and the name of the school was changed to Southern Branch of the University of California. On February 1, 1927, the name of the institution was changed to University of California at Los Angeles. The removal to the present site from North Vermont Avenue took place in August, 1929, and instruction in all departments began in the new buildings on September 23, 1929.

Leland Stanford Junior University, given by Leland Stanford and his wife, Jane Lathrop Stanford, in memory of their son, Leland Stanford, Junior, was established under an act of the California legislature approved on March 9, 1885. The corner-stone of the inner quadrangle was laid on May 14, 1887, and the university was opened to students on October 1, 1891. In connection with the school of biological sciences of this university there is maintained one of the finest marine laboratories in the world, the Hopkins Marine Station, situated on Cabrillo Point at Pacific Grove on Monterey Bay. The first unit of this laboratory, the Alexander Agassiz Laboratory, was built in 1917, and the second unit, the Jacques Loeb Laboratory, was completed in July, 1928. There is also maintained a Food Research Laboratory, which was organized in 1921.

The Lick Observatory, connected with the University of California, was erected in 1887 on Mt. Hamilton at a height of 1,283 meters above sea level. In the same year Pomona College at

Claremont and Occidental College at Los Angeles were established.

The California Institute of Technology was founded at Pasadena in 1891 as a college, a graduate school and an institute for research in science, engineering and the humanities. At the present time this institute includes the Norman Bridge Laboratory of Physics, the gift of the late Dr. Norman Bridge, of Chicago; the High Potential Research Laboratory, provided by the Southern California Edison Company; the Gates Chemical Laboratory, the gift of C. W. and P. G. Gates; the Research Laboratory of Applied Chemistry; the Laboratory of Steam Engineering and Engineering Research, the funds for which were provided in part by Dr. Norman Bridge; the Daniel Guggenheim Aeronautical Laboratory, for which the Daniel Guggenheim Fund provided funds for the construction of the laboratory and for its operation for a period of ten years; the Seismological Research Laboratory, operated jointly by the California Institute and the Carnegie Institution of Washington; Dabney Hall of the Humanities, the gift of Mr. and Mrs. Joseph B. Dabney; and the William B. Kerckhoff Laboratories of the Biological Sciences. Besides these, there is Throop Hall, the central building on the campus, which was the first building of the present group and was the gift of a large number of donors; Culbertson Hall, a beautiful auditorium seating 500 persons, and a marine station at Corono del Mar, near Laguna Beach. For work in plant genetics there is a ten acre farm at Arcadia, about five miles from the institute.

In addition, there is the Atheneaum, an autonomous club, the object of which is to provide a place and opportunity for contacts between the distinguished foreign scientists and men of letters temporarily in residence from time to time at the California Institute, the Mt. Wilson Observatory and the Henry E. Huntington Library and Art Gallery, the staffs and graduate students of those institutions, and the patrons and friends of science and education in southern California making up the California Institute associates.

Whittier College, at Whittier, was established in 1901.

The Mt. Wilson Observatory, situated on Mt. Wilson near Pasadena, at an altitude of 1,742 meters, was founded in 1904 as an offshoot of the Yerkes Observatory. It is one of the units of the Carnegie Institution of Washington.

The University of Redlands was established at Redlands in 1907.

The Scripps Institution of Oceanography was founded in 1912 through the generosity of Miss Ellen Scripps and others. It is situated at La Jolla. It was originally the Scripps Institution for Biological Research, the name having been changed in October, 1925. This institution is a part of the University of California.

Besides these institutions for study and research, California has many others of a more special nature. Especially noteworthy are her museums. The local scientific organizations are numerous and active. Some are local, while others are western sections or branches of organizations which are national in scope. The scientific establishments maintained by the state must not pass unnoticed. It may be mentioned that California was the first state to protect itself by legislation and quarantine against the introduction of insect pests. In 1881 quarantine laws were passed which were not only sound, but also were novel in their character. Few states to-day have as fine a group of distinguished workers in economic entomology as are to be found in the California Department of Agriculture.

From this brief survey of the growth of the educational and scientific institutions in California it is evident that the

state has been as fortunate in its cultural development as it is in its natural advantages.

South of California lies Mexico, a country which is all too little known to most of our fellow citizens. How many people realize that the University of Mexico was founded in 1554, eighty-two years before the establishment of Harvard?

One of the features of the Pasadena meeting will be the cooperation of the scientific men of our great neighbor to the south. The undersecretary of national education, Señor Don Moises Saenz, will speak on the Mexican educational program, and Dr. Manuel Gamio, well known for his work on the ancient temples of San Juan Teotihuacan, has been invited to discuss recent archeological work in Mexico.

Another special feature of the program will be a session in honor of Dr. David Starr Jordan, president emeritus of Leland Stanford Junior University, a most able biologist, an unusually inspiring teacher, and a constructive administrator, who has recently celebrated his eightieth birthday.

An unusually large and interesting series of special symposia and lectures under the leadership of outstanding authorities have been arranged in many different lines of science. The titles of some of these are: major problems in modern oceanographic research; the antiquity of man; high voltage x-ray tubes and their medical and biological possibilities; the physics of crystals; the present status of the problem of nuclear structure; the production of high energy electrical particles; photosynthesis; photochemistry and band spectra; reaction mechanisms and chemical kinetics; quantum mechanics of the chemical bond; the internal structure of stars; earthquake-proof structures; seismological problems; the Colorado River dam and aqueduct; ecological problems of the Pacific coast; and problems in genetics.

A popular lecture will be given each evening at 8:30 in the Greek Theater in Griffith Park, Los Angeles. On Monday, June 15, Dr. Franz Boas, president of the association, professor of anthropology at Columbia, and dean of American anthropologists, will speak on "Race and Progress." On Tuesday Dr. H. D. Arnold, director of research, Bell Telephone Laboratories, New York, will give an experimental lecture entitled "Science Listens." On Wednesday Dr. Arthur L. Day, director of the Geophysical Laboratory of the Carnegie Institution of Washington, will speak on "The Present Status of Seismology." On Thursday Dr. Charles A. Beard, author of "The Rise of American Civilization," "American Party Battles," etc., will speak on "Scientists and History." On Friday there will be held a symposium on "The Impact of Science upon Civilization, Past, Present, and Future" conducted by a historian, an economist and a scientist.

Scientific exhibits will be an important feature of this meeting, and a series of excursions will provide an opportunity for visiting nearby places of special interest under the leadership of competent guides.

As usual, practically all fields of science will be represented in the sessions of the sections and of their related societies. There will be many joint sessions of two or more organizations, and many symposia of invited papers on timely topics. A great many sessions will be devoted to the reading of technical contributions.

With the exceptionally interesting program which has been arranged, and taking place in the inspiring physical and cultural environment of southern California, the Pasadena meeting can not fail to be one of the most successful meetings of the association.

AUSTIN H. CLARK

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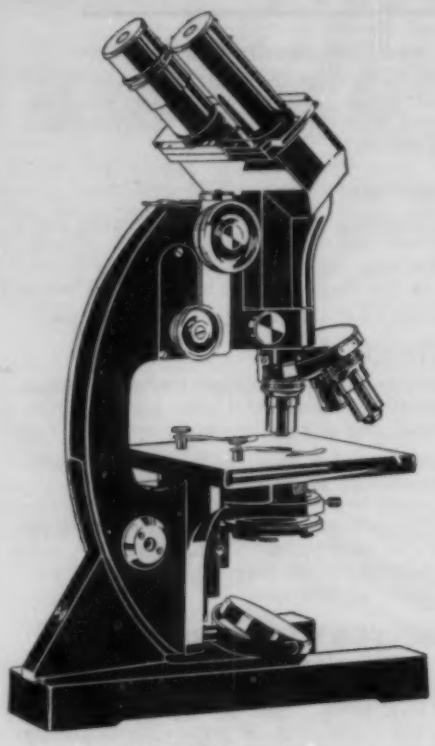

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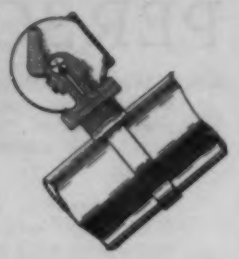

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